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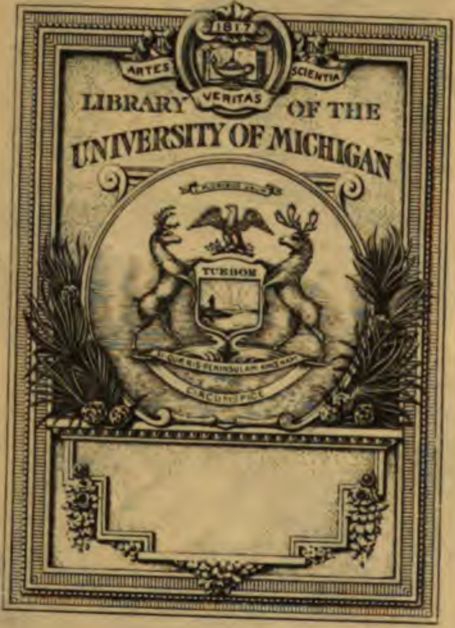

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ON

THE PRINCIPLES OF SCIENCE

WITH THEIR APPLICATION TO PRACTICAL PURSUITS.

PRACTICAL CHEMISTRY.

8

LONDON:
HOULSTON AND STONEMAN, 65, PATERNOSTER ROW;
WM. S. ORR AND Co., AMEN CORNER.
MDCCCLVI.

PRACTICAL CHEMISTRY:

INCLUDING

THE THEORY AND PRACTICE OF ELECTRO-DEPOSITION;

PHOTOGRAPHIC ART;

THE CHEMISTRY OF FOOD,

With a Chapter on its Adulterations;

AND

THE CHEMISTRY OF ARTIFICIAL ILLUMINATION.

BY

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LONDON:
HOULSTON AND STONEMAN, 65, PATERNOSTER ROW;
WM. S. ORR AND CO., AMEN CORNER.
MDCCCLVI.

PREFACE.

The present Volume of the Circle of the Sciences embraces, to a very limited extent only, the great subject of Practical Chemistry; but it includes those subjects which are invested with a popular character, and on which the public mind may be considered more particularly open to information. Most of the other branches of the subject become either manufacturing or professional; and with such subjects it is not intended to interfere in this series, which may be considered as elementary in its character, reserving such subjects for treatment in another series with which it is intended to follow the present one.

The chief value of the present Volume arises from its strictly practical treatment of its subjects. In the important branch of Electro-deposition, Mr. Gore has given his formulæ in a plain and practical manner, the information being drawn from his own practice, and from the practice of the establishments most advanced perhaps in the world in this department of science.

Mr. Sparling has treated that most fascinating of all pursuits, Photography, in the same spirit, giving in detail his own practice; but, from the nature of the subject, and from the number of accomplished and scientific men who have written on the subject in a desultory form, and from the circumstance of some of these having experimented with him and mixed up his own investigations with theirs, more of the general literature of the subject has been included in his Treatise than in the former.

Of Professor Moleschott's Treatise "Lehre der Nahrungs Mittel," it is only necessary to say that it has gone through four large editions in Germany, and has been translated into two foreign languages, in each case with great success. The Conductor trusts the present translation, with Dr. Scoffern's Chapter on Adulterations, will be found useful in directing the public mind, as well as legislature, to an adjustment of that question. The translator regrets that, owing to his absence on the Continent while the work was passing through the press, the errata are unduly numerous. A list of the principal is given, and the student is requested to correct them in the margin.

In respect to the Treatise on Artificial Illumination, the Author prefers for the present to remain unknown; it must, therefore, rest on its own merits. The Conductor can only add his own testimony to the internal evidence it offers, that there is no writer of the day more competent from position and experience to write on the subject. How far, however, the objects have been fulfilled it remains for the reader to decide. Actuated by the conviction that no chemical author, of whatever talent, fame, or experience, could treat of subjects so diverse as the numerous branches of technological chemistry, otherwise than as a compiler and a theorist in some, we have confided each separate branch to the responsibility of some one author who had previously devoted to it his special attention, and was favourably known in relation to it: hoping by this means to produce a series of Treatises full of practically useful information.

Amen Corner, Paternoster Row,
September, 1856.

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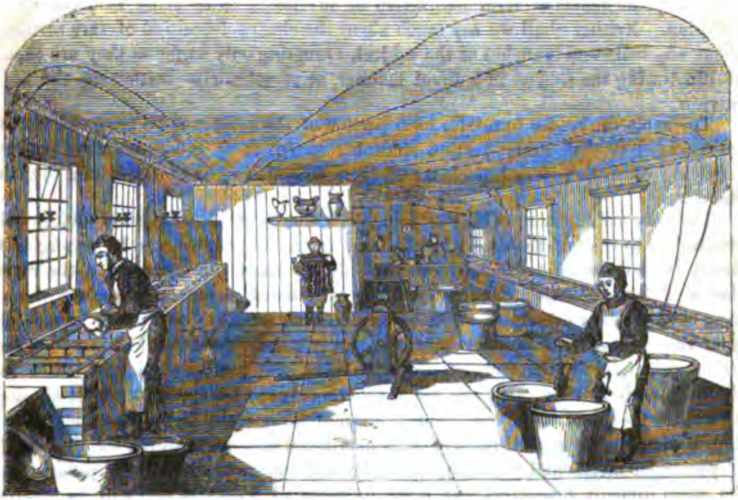

ELECTRO-DEPOSITING ROOM.

ELECTRO-METALLURGY.

◆

THE THEORY OF ELECTRO-DEPOSITION.

Introductory Remarks.—As the ultimate object of this treatise is to enable the reader to work in an electroplate manufactory in a commercially successful manner; we shall endeavour to include within its pages, as far as the limited space will allow, every portion of the subject calculated to assist him in obtaining that result, excluding from it every other portion which does not contribute towards that object.

With this view we shall include the *principles* or *theory* of electro-deposition, because every workman in an electroplate manufactory is certain to meet with difficulties, which no amount of practical knowledge or experience will enable him to overcome without a perfect knowledge of the theoretical principles. These difficulties may be new ones, such probably as he has never seen before, and no doubt, in some cases, such as no one else has ever seen; a knowledge of the theory will here enable him to apply its principles to the difficulties, and suggest remedies, some of which are almost sure to be successful.

We shall also include the *practice* of the subject; because, after all, its success depends on careful manipulation; for with ever so perfect a knowledge of principles, without a perfect knowledge of the application of those principles in the form of practical rules and practical manipulation, success cannot possibly be attained. With the same end in view, we shall avoid saying anything about the history of the subject, or the claims of rival discoverers or inventors, these being subjects for the historian. Neither shall we say much about the electro-deposition of rare metals, or about any collateral branches of the subject, excepting only so far as they are capable of illustrating the subject in a direct manner, or of otherwise furthering the object in view.

To enable the reader to master each portion of the subject as he proceeds, we have so arranged it that every portion shall be, so far as it goes, complete in itself, requiring no anticipatory knowledge of more advanced parts to enable him to understand it.

The only arrangement of the subject which admits of this important object being attained, is to treat of the theory before treating of the practice, and by arranging the theory in an *inductive* order. In other words, we shall commence with the various classes of facts on which electro-deposition is founded, and ascending from these to the general laws or principles, chemical or electrical, which govern them. Proceeding from the theory to the practice, arranging all in a *deductive* order, and applying theoretical principles in the form of practical rules, the results cannot be other than successful. Beginning with the more general rules which apply to all electro-deposition processes, and to the electro-deposition of all metals, and proceeding, step by step, to those more special rules of manipulation which are required for the working of particular metals and solutions, the necessary requirements for the production of the more difficult substances and more complicated works of art will be attained. Through the whole treatise, the reader will thus be led gradually from the most common and well-known facts to the most complex and difficult applications of electro-deposition.

In accordance with this plan, the subject will commence with a review of such facts of electro-deposition as every man possessing the few necessary materials, which are easily procurable, may readily verify for himself. On these facts the whole subject throughout will be based. From them we shall proceed to the circumstances or *conditions* under which they occur, namely, the *causes* of electro-deposition. The principles will be inferred from the facts as we proceed, until we arrive at the more abstract conditions of the phenomena.

The facts will be based on numerous experiments, in which instances where deposition does occur, as well as experiments in which it does not occur, will be cited. These investigations will satisfy the reader that in all cases where deposition does occur, certain conditions are invariably present; and where it does not occur, one or more of those conditions is invariably absent; and, therefore, that the conditions observed are the causes of the phenomena. Another and more ultimate reason for mentioning negative as well as positive instances is, that in practical working it is nearly as important to know what will prevent deposition, as to know what will produce it.

The following table exhibits the phenomena of electro-deposition arranged in an inductive order, suitable for learning the subject theoretically, and without immediate reference to its practical applications. The first portion of the table contains the *facts* of electro-deposition, divided into seven classes, under which may be ranged the whole known facts of the science. The second portion contains the *principles* or *conditions* under which those facts are manifested; these are also divided into seven classes, which are capable of including all the known conditions or causes of electro-deposition.

A.—Facts.

1. Deposition by one metal and one liquid.
2. Deposition by two metals and one liquid.
3. Deposition by one metal and two liquids.
4. Deposition by two metals and two liquids.
5. Deposition by connecting either of the foregoing arrangements (except the first) with a separate depositing liquid.
6. Deposition by connecting other sources of depositing power with a separate depositing liquid.
7. Deposition by combinations of the foregoing.

B.—Principles.

1. Chemical conditions of deposition.
2. Electrical conditions of deposition.
3. Thermic conditions of deposition.
4. Mechanical conditions of deposition.
5. Mathematical conditions of deposition.
6. Logical conditions of deposition.
7. Ontological conditions of deposition.

This arrangement has been used with much success in teaching the theoretical part of electro-deposition, enabling the pupils to understand each portion clearly as they proceeded. The plan adopted was—

First, to exhibit before the pupils numerous experiments of each class of facts in succession, including positive cases in which deposition did occur, as well as negative ones in which it did not occur.

Second, to place each of the theoretical principles in succession before them in the form of a hypothetical question, referring them to the various facts on which it is founded, and leaving them to observe for themselves whether or not the principle there stated was borne out, allowing them to draw their own conclusions. By this method they were soon led to observe, that, wherever deposition occurred, certain conditions were present, and that where it did not occur those conditions were absent.

When treating of the laws and principles of deposition, the reader will be referred back to the facts upon which they are based; so, when describing its practical applications, he will in like manner be referred to the laws or principles for his guidance; his knowledge of the practice will thus be based in a great measure upon the principles, as the principles will be deduced from the facts, which, as we have said before, are within the reach of every one to repeat and prove for himself.

The practical part will treat in succession of the general rules for working all the different processes of washing or dipping, whether by single cell, battery, or other process. The requisites for preparing good depositing solutions, both for simple metals and alloys, with methods of making solutions generally, and of working them; suitable sources of electricity, either by the magneto-electric machine or other batteries, together with their construction; as well as instructions for regulating the quantity and intensity of the current; regulating the quantity and quality of the deposited metal; cleaning and preparing metallic surfaces for receiving adhesive and non-adhesive deposits; copying works of art in various substances; elastic moulding; preparation of non-conducting surfaces to receive a deposit; multiplication of works of art by deposition; deposition, by the various processes, of such metals and their alloys as antimony, bismuth, zinc, cadmium, tin, lead, iron, cobalt, nickel, copper, brass, german silver, mercury, silver, gold, platinum, and palladium; chemical relations of the cyanides of gold and silver; manufacture of cyanide of potassium; recovery of gold and silver from damaged solutions; and a full list of patents upon electro-deposition.

THEORETICAL DIVISION OF THE SUBJECT.

1. **Facts.**—*One Metal in One Liquid.*—There are various modes in which deposition of one metal upon another may take place, and they may be classed as follows:—

1st. By the simple immersion of *one* metal in *one* liquid (Fig. 1), namely, by putting the metal to be coated into a solution of the metal to be deposited, and allowing it to remain a longer or shorter period of time, the liquid being at a suitable temperature; for instance, if we immerse a piece of clean iron in a solution of sulphate of copper, it will become coated with copper, but if we immerse a piece of silver in that liquid it will not become so coated.

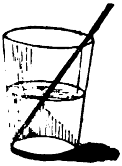
Fig. 1.

2nd. *Two Metals in One Liquid.*—By the immersion of *two* metals in *one* liquid (Fig. 2), the two metals being in contact with each other; for instance, if we connect a piece of silver A and a piece of iron B together, and immerse them in a solution of sulphate of copper C, the silver will become coated with copper as well as the iron; but if a piece of silver in contact with a piece of gold or platinum is immersed in the same liquid, it will not become coated. We have already seen that silver immersed alone in such a liquid will not receive a deposit of copper.

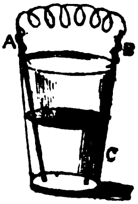

Fig. 2.

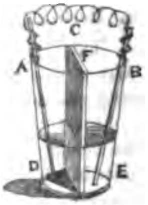

Fig. 3.

3rd. *One Metal in Two Liquids.*—By the immersion of *one* metal (*i.e.*, one *kind* of metal) in *two* liquids D and E (Figs. 3 and 4), the liquids being prevented from mixing with each other either by a porous partition F (Fig. 3) of bladder, thin wood, unglazed earthenware, or other porous material which will allow the two liquids to touch each other through its pores; the piece of metal being either bent so as to dip into each liquid, or cut into two portions, and its two ends united by a wire C, the end or piece to receive the deposit being immersed in one liquid, and the other piece in the other liquid (Fig. 3); or the two liquids being put in a deep narrow vessel, the heavier one being poured in first, and the lighter one poured carefully above it so as not to mix them together, and the piece of metal being in the form of a rod or wire placed vertically in the two liquids (Fig. 4); for instance, if the lower liquid consists of a solution of sulphate of copper and the other of dilute sulphuric acid, and a piece of copper is immersed in both liquids, that part of it which is in the sulphate solution will become coated with copper, whilst that in the acid liquid will be partly dissolved; but if, instead of copper, we use a piece of platinum, it will neither be dissolved nor receive a metallic deposit.

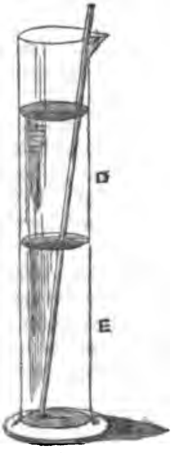

Fig. 4.

4th. *Two Metals in Two Liquids.*—By the immersion of *two* metals A and B (Fig. 5) in *two* liquids, D and E, the two being, as in the last arrangement, either separated by a porous diaphragm F, or poured one above the other, the two metals being immersed one in each liquid, and connected together by a wire C; for instance, if one liquid is dilute sulphuric acid, and the other a solution of sulphate of copper, and a piece of copper is immersed in the dilute acid and a piece of silver in the metallic solution, the two metals being thus in mutual contact, the piece of copper will dissolve, and the silver receive a deposit of copper; but if we immerse a piece of platinum in the dilute acid with the silver in the sulphate solution, the platinum will not dissolve, nor the silver receive a metallic deposit.

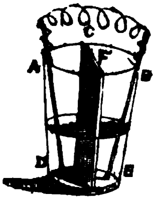

Fig. 5.

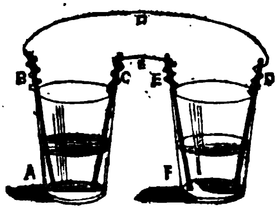

Fig. 6.

5th. *Separate Depositing Liquid with all the others.*—By connecting any one of the foregoing arrangements by means of wires with two separate pieces of metal of a similar kind immersed in a separate and suitable liquid (Fig. 6); for instance, if we take the arrangement of two metals in one liquid, such as iron B and copper C, in a solution of sulphate of copper A; or zinc B and silver C in dilute sulphuric acid A, and connect them by two separate wires D and E with two pieces of copper D and E immersed in a solution of sulphate of copper F contained in a separate vessel, the piece of copper E connected with the silver will dissolve, whilst the other piece D which is connected with the zinc will receive a deposit of copper; but if we substitute a solution of sulphate of zinc, freely acidulated with sulphuric acid, for the solution of sulphate of copper F, and two pieces of platinum for the pieces of copper, the one piece of platinum will not dissolve nor the other receive a metallic deposit.

6th. *Separate Depositing Liquid with any other Source of Power.*—By connecting the pieces of metal in the separate depositing liquid with any other source of depositing power, such as a magneto-electric machine, cell, or battery.

2. In these arrangements it will be observed that we have—1st, deposition by one metal and one liquid; 2nd, by two metals and one liquid; 3rd, by one metal and two liquids; 4th, by two metals and two liquids; 5th, by a separate depositing liquid and metals connected with either of these; and 6th, by a separate depositing liquid and metals connected with any other source of depositing power. These six classes and their combinations are capable of including all the known cases of electro-deposition.

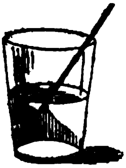

Fig. 7.

3. Under the head of each of these classes will be mentioned a number of experiments with various metals and liquids, and it would be advisable for the student to try a few experiments, as he proceeds, both of deposition and non-deposition of each class, in order to fix the facts more firmly in his memory, and give him a fuller comprehension of the principles.

4. **Depositing Arrangement No. 1.**—Deposition by one metal and one liquid (Fig. 7) takes place in the following instances :—

Hydrochlorate of Terchloride of Antimony.—In a solution of hydrochlorate of terchloride of antimony (the ordinary chloride of antimony, as prepared for pharmaceutical purposes), bismuth, zinc, tin, lead, brass, and german silver become coated with antimony; whilst antimony, iron, nickel, copper, silver, gold, and platinum do not become coated.

Chloride of Bismuth.—In a solution of acid hydrochlorate of bismuth oxide (chloride of bismuth), zinc, tin, lead, and iron deposit the bismuth upon themselves; whilst antimony, bismuth, copper, brass, german silver, gold, and platinum do not.

Sulphate, Chloride, Nitrate, or Acetate of Zinc.—In a solution of either sulphate, chloride, nitrate, or acetate of zinc, neither antimony, bismuth, zinc, tin, lead, iron, nickel, copper, brass, german silver, silver, gold, or platinum become coated with zinc.

Protochloride of Tin.—In a solution of protochloride of tin, zinc and lead become tinned; whilst antimony, bismuth, tin, iron, nickel, copper, brass, german silver, silver, gold, and platinum receive no deposit.

Hyponitrate, Nitrate, or Acetate of Lead.—In a solution of hyponitrate, nitrate, or acetate of lead, zinc receives a coating of lead; whilst antimony, bismuth, tin, lead, iron, nickel, copper, brass, german silver, silver, gold, and platinum receive no deposit.

Ferrous Sulphate.—"Zinc," as Fischer says, "immersed in a perfectly neutral solution of ferrous sulphate (protosulphate of iron) contained in a stoppered bottle, throws down metallic iron, which is deposited partly on the zinc;" but in this solution neither antimony, bismuth, tin, lead, iron, nickel, copper, brass, german silver, silver, gold, or platinum receive any metallic deposit.

Sulphate of Copper.—In a solution of sulphate of copper, zinc, tin, lead, and iron become coated with copper; whilst antimony, bismuth, nickel, copper, silver, gold, and platinum do not.

Chloride of Copper.—In a solution of chloride of copper, bismuth, zinc, tin, lead, and iron receive a copper deposit; whilst antimony, nickel, copper, silver, gold, and platinum do not.

Nitrate of Copper.—In a solution of nitrate of copper, zinc, tin, lead, and iron become coated; whilst antimony, bismuth, nickel, copper, silver, gold, and platinum receive no deposit.

Dichloride of Copper.—With a solution of dichloride of copper in liquid ammonia, or of oxide of copper in a solution of sal-ammoniac, zinc receives a deposit; whilst antimony, bismuth, tin, lead, iron, nickel, copper, silver, gold, or platinum do not.

Mercurious Salts.—Solutions of mercurious salts have their metal deposited by arsenic, antimony, bismuth, zinc, cadmium, tin, lead, iron, copper, and brass, also by the alloys of silver with zinc, tin, lead, or copper.

Nitrate of Mercury.—A solution of nitrate of mercury yields its metal to bismuth, zinc, cadmium, lead, iron, or copper, and, if acidulated with nitric acid, to antimony also; but not to silver, gold, or platinum.

Acetate of Mercury.—Iron deposits mercury from a solution of acetate of mercury.

Silver Solutions.—The following metals, viz., manganese, arsenic, antimony, bismuth, zinc, cadmium, tin, lead, iron, copper, and mercury, deposit silver from its solutions in the metallic state; an aqueous solution of nitrate of silver yields its metal to manganese, arsenic, antimony, bismuth, zinc, tin, lead, iron, nickel, copper, brass, and german silver; but not to silver, gold, or platinum. Lead and tin deposit the silver most quickly; then follow the other metals in this order, cadmium, zinc, copper, bismuth, antimony, arsenic, mercury. Arsenic deposits silver from the alcoholic solution of nitrate of silver; antimony receives a coating of silver either in the aqueous sulphate or alcoholic nitrate; bismuth deposits silver from the alcoholic nitrate, but not from the aqueous sulphate; zinc receives a silver deposit in the alcoholic nitrate; tin becomes silvered in the alcoholic nitrate, but more quickly in the aqueous sulphate; iron deposits silver from the sulphate of silver; but not from the alcoholic nitrate; copper deposits it from the aqueous sulphate or alcoholic nitrate; brass and the alloys of silver, with zinc, tin, or lead, deposit silver from silver solutions completely. In a solution of the double cyanide of silver and potassium (the ordinary plating liquid), zinc, lead, and copper become silvered; also brass and german silver, but more slowly; whilst antimony, bismuth, tin, iron, nickel, silver, gold, and platinum do not.

Gold Solutions.—From an acid solution of terchloride of gold, most of the base metals, likewise mercury, silver, platinum, and palladium deposit gold, generally in the metallic state, but not always; arsenic rapidly deposits gold in this solution; antimony, tellurium, and bismuth become gilded; zinc, cadmium, lead, iron, cobalt, mercury, silver, platinum, and palladium deposit the gold; whilst titanium, tungsten, molybdenum, and chromium do not. In a solution of the double cyanide of gold and potassium, zinc quickly becomes gilded, and copper, brass, and german silver slowly; whilst antimony, bismuth, tin, lead, iron, nickel, silver, gold, and platinum do not.

Bichloride of Platinum.—Platinum is deposited from a solution of its bichloride by arsenic, antimony, tellurium, bismuth, zinc, cadmium, tin, lead, iron, cobalt, nickel, copper, brass, german silver, mercury, and silver; but not by gold or platinum.

5. *Observations upon Class of Instances No.* 1.—In reviewing all these instances, we may make the following observations:—1st, that various metals by mere immersion in solutions of other metals, at the ordinary temperature of the atmosphere, sometimes become coated with a deposit of metal, and sometimes not; 2nd, that no metal becomes coated by mere immersion in a solution of the same metal—for instance, zinc does not become coated with zinc in a solution of sulphate of zinc; copper with copper in a solution of its sulphate, gold with gold in its chloride; 3rd, that the baser metals, especially zinc, cadmium, tin, lead, and iron, become coated more frequently than the noble metals, especially gold and platinum; 4th, that solutions of base metals, especially of zinc and iron, yield their metal less frequently than those of the noble metals, especially those of gold and platinum; 5th, that of all the ordinary metals mentioned in the foregoing instances, zinc deposits metal from the greatest number of solutions, and appears to have the strongest depositing power; 6th, that the coherent and adhesive deposits obtained are in all cases exceedingly thin; and 7th, that oftentimes the deposited metal, whatever its kind may be, has the appearance of a black or dark-coloured powder on its surface, especially when it has been deposited very rapidly; and that sometimes it exhibits its ordinary colour and appearance, especially if its outer portion is rubbed off.

6. To this mode of depositing belongs the process of tinning brass articles (wash tinning), by boiling them in water containing a salt of tin and bitartrate of potash; the process of silvering brass nails, buttons, hooks and eyes, buckles, &c., by rubbing them with any of the well-known silvering compositions moistened with water; also the water gilding process, &c.

7. **Depositing Arrangement No. 2.** — *Deposition by Two Metals and One Liquid.*—The following instances belong to the class of deposition by two metals and one liquid, the two metals being either in mutual contact (touching each other either above or beneath the liquid), or connected together by a wire.

Chloride of Antimony.—For instance, if we immerse a piece of antimony A, in contact with a piece of zinc B, in a solution of the ordinary chloride of antimony C, it will receive a coating of antimony; or if we immerse a piece of platinum in contact with a piece of tin in this

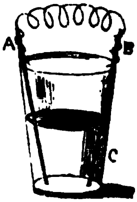

Fig. 8.

liquid, it will receive a deposit of antimony; but if we immerse a piece of antimony in contact with a piece of platinum, or a piece of platinum in contact with a piece of silver in this liquid, it will receive no metallic deposit.

Chloride of Bismuth.—In a solution of chloride of bismuth, brass in contact with a piece of zinc, copper in contact with tin, or german silver with iron, receives a deposit of bismuth; but brass in contact with a piece of gold, gold in contact with silver, or german silver with platinum, receives no deposit.

Sulphate, Chloride, or Nitrate of Zinc.—With a solution of either sulphate, chloride, or nitrate of zinc, no metal of any pair of metals selected from amongst the following, will receive a deposit of zinc: antimony, bismuth, zinc, tin, lead, iron, nickel, copper, mercury, silver, gold, platinum, or palladium.

Protochloride of Tin.—With a solution of protochloride of tin, either antimony, tin, or copper, immersed in contact with zinc or lead, will receive a coating of tin; but antimony in contact with tin, tin with silver, copper with iron, or either gold or platinum with copper will not receive a deposit.

Hyponitrite of Lead.—With a solution of hyponitrite of lead, either tin, copper, or brass, in contact with a piece of zinc, will receive a deposit of lead; but tin in contact with copper, copper with lead, or brass with platinum, receives no deposit.

Nitrate of Lead.—With a solution of nitrate of lead, either copper, brass, or silver, in contact with zinc, receives a coating of lead; but copper in contact with iron, brass with tin, or silver with copper, receive no such coating.

Protosulphate of Iron.—With a saturated solution of protosulphate of iron, platinum in contact with zinc receives a deposit of iron; but in contact with copper it receives no metallic deposit.

Chloride of Nickel and Ammonia.—In a solution of the double chloride of nickel and ammonia, copper in contact with zinc receives a deposit of nickel; but in contact with silver it does not receive such a deposit.

Sulphate of Copper.—In a solution of sulphate of copper, brass in contact with zinc; or tin, german silver, silver, or platinum, in contact with iron, receives a deposit of copper; whilst silver in contact with antimony, or platinum in contact with brass, receives no deposit.

Oxide of Copper in Ammonia.—In a solution of oxide of copper in ammonia, platinum in contact with zinc receives a deposit; but silver in contact with iron does not.

Nitrate of Mercury.—In a solution of nitrate of mercury, silver in contact with either zinc or iron, or platinum in contact with copper, receives a metallic deposit; but platinum in contact with silver does not.

Nitrate of Silver.—In a solution of nitrate of silver, gold in contact with zinc receives a deposit of silver; but in contact with platinum it does not.

Bichloride of Platinum.—In a solution of bichloride of platinum, platinum in contact with zinc becomes coated with platinum; but in contact with gold it receives no such coating.

8. *Observations upon Class of Instances No.* 2.—The following general observations may be made upon the foregoing facts:—1st, that in some instances deposition does, and in others it does not, occur; 2nd, that no metal will cause another metal to be coated by this method, unless it can coat itself in the same liquid by simple immersion—for instance, zinc cannot coat itself with zinc in solutions of zinc, neither can it cause other metals to become coated with that metal in those solutions; copper cannot coat itself with zinc in a solution of sulphate of zinc, or with tin in a solution of chloride

of tin, neither can it cause silver, gold, or any other metal, to become coated with zinc or tin, in those liquids; 3rd, that one of the two metals which receive a deposit by this method, derives its power of receiving the deposit by virtue of its contact with the other metal; 4th, that any metal which has the power of coating itself by simple immersion in a given liquid, can by this method cause other metals which do not coat themselves by simple immersion in that liquid to become coated—for instance, zinc, tin, and iron coat themselves with copper by simple immersion in a solution of sulphate of copper, and silver, gold, and platinum do not; but if either of the former metals be connected with either of the latter, and the two immersed together in that liquid, the latter metals as well as the former will become coated with copper; 5th, that base metals, and especially zinc, have generally the power of causing other metals to become coated by this method; whilst the noble metals, and especially gold and platinum, rarely possess this power; 6th, that by this method metal is deposited much more frequently from solutions of the noble metals, than from those of the base ones; and 7th, that thick deposits of metal may be obtained by this method, provided the action is continued sufficiently long, and the liquid properly renewed.

9. Depositing Arrangement No. 3.—*Deposition by One Metal and Two Liquids—Chloride of Antimony.*—The following instances belong to deposition by the immersion of one metal in two liquids, D and E (Fig. 9), separated by a porous diaphragm F, the metal being either in two pieces connected together by a wire or wires C, or in one piece, and bent so as to dip into both liquids; the diaphragm may be dispensed with, as already explained (1), by pouring the lighter liquid carefully above the other, and placing the piece of metal vertically in the two liquids; if two pieces of antimony, A and B, connected together by a wire or wires C, are immersed, one in dilute nitric acid D, and the other in a solution of chloride of antimony E, the piece in the dilute acid will dissolve, whilst, that in the chloride solution will receive a metallic deposit.

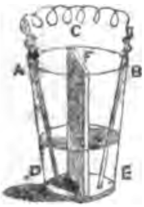

Fig. 9.

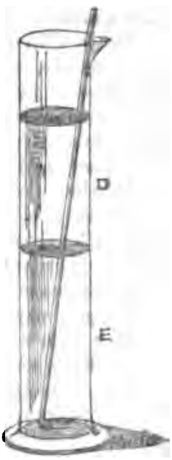

Fig. 10.

Chloride of Bismuth.—If two pieces of antimony are immersed in the previous manner, one in hydrochloric acid, and the other in a solution of chloride of bismuth, that in the acid will dissolve, and the other receive a coating of bismuth.

Sulphate of Copper.—With antimony, in dilute hydrochloric acid on one side, and in a solution of sulphate of copper on the other, a deposit of copper is obtained.

Chloride of Bismuth.—With bismuth in hydrochloric acid on one side, and in a solution of chloride of bismuth on the other, a free deposit of bismuth is soon obtained.

Chloride of Zinc.—If a piece of zinc is bent so as to dip into dilute hydrochloric acid on one side, and into a neutral solution of chloride of zinc on the other, a free deposit of zinc will be found upon the end in the metallic solution after a period of twelve hours.

Solution of Acetate of Zinc.—With zinc in a solution of acetate of zinc on one side, and in dilute sulphuric acid on the other, that in the dilute acid will dissolve, whilst the other end will receive a metallic deposit.

Iron in Chloride of Antimony.—With iron in dilute sulphuric acid on one side, and in a solution of chloride of antimony on the other, the end in the metallic solution will receive a deposit of antimony, whilst that in the dilute acid will dissolve.

Iron in Sulphate of Zinc.—With iron in dilute sulphuric acid on one side, and in a solution of sulphate of zinc on the other, no deposit of zinc is obtained in twelve hours; similarly with iron, dilute sulphuric acid, and a solution of protosulphate of iron, no deposit occurs in twelve hours.

Tin in Chloride of Tin.—With tin in dilute hydrochloric acid on one side, and in a solution of chloride of tin on the other, a deposit of tin is obtained.

Zinc in Sulphate of Zinc.—With zinc in dilute sulphuric acid, and in a solution of sulphate of zinc, a free deposit of zinc occurs in twelve hours.

Bismuth in Nitrate of Bismuth.—With bismuth in dilute nitric acid, and in a solution of acid nitrate of bismuth, a thin deposit of bismuth is found in twelve hours.

Copper in Sulphate of Zinc.—With copper in dilute sulphuric or dilute nitric acid on one side, and in a solution of sulphate of zinc on the other, no deposit of zinc occurs in twelve hours.

Brass or Copper in Sulphate of Copper.—With brass or copper in dilute sulphuric acid on one side, and in a solution of sulphate of copper on the other, a deposit of copper is obtained in twelve hours; similarly with copper in dilute hydrochloric acid, and in a solution of chloride of copper, a metallic deposit occurs.

Silver in Plating Liquid.—With silver in either dilute sulphuric, or dilute nitric acid on one side, and in a solution of sulphate of copper on the other, no deposit of copper takes place in twelve hours; but with silver in a solution of cyanide of potassium on one side, and in the double cyanide of potassium and silver on the other, a free deposit of silver takes place upon the end or piece in the latter solution.

Platinum in Nitrate of Copper.—With platinum in aqua regia on one side, and in either a solution of nitrate of copper, the ordinary cyanide gilding solution, or a solution of bichloride of platinum on the other, no deposit of copper, gold, or platinum occurs.

10. *Observations on Class of Instances No.* 3.—1st, it appears, that in this class also we obtain negative as well as positive instances; 2nd, that by this arrangement unlike the previous classes, almost any metal may cause the same metal to be deposited—for instance, zinc may deposit zinc, copper deposit copper, and silver deposit silver; 3rd, that by it even a noble metal may cause the deposition of a base metal, provided we have a suitable combination of liquids; for instance, if a piece of gold or silver is immersed in a strong solution of cyanide of potassium on one side, and in a solution of sulphate of copper or chloride of antimony on the other, the end in the free cyanide solution will dissolve, whilst that in the copper antimony solution will receive a deposit; 4th, that the metal or end which receives a deposit, derives that power from its contact with the metal in the other liquid; 5th, that, as a general rule, base metals have a greater power of causing deposition by this method than the noble ones; 6th, that the noble metals are more readily and more often deposited than the base ones; and 7th, that we may produce thick and coherent deposits by this method.

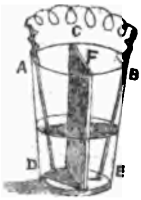

Fig. 11.

11. **Depositing Arrangement No. 4.**—*Deposition by Two Metals and Two Liquids.*—The following instances belong to the class of deposition produced by the immersion of two metals, A and B (Fig. 11), in two liquids, D and E, the metals being in mutual contact or connected together by a wire C, and the liquids separated by a porous partition F.

Zinc Depositing Antimony.—If a piece of antimony A be immersed in a solution of chloride of antimony D, and a piece of zinc B is immersed in dilute sulphuric acid E, and the two metals are connected together by a wire or wires C, a free deposit of antimony upon the metal A will take place in twelve hours.

Tin Depositing Zinc.—With tin in hydrochloric acid, and zinc in a neutral solution of sulphate of zinc, a deposit of zinc is obtained in the metallic solution.

Iron Depositing Antimony.—With iron in dilute hydrochloric acid, and antimony in chloride of antimony, a copious deposit of antimony takes place in twelve hours.

Copper Depositing Zinc.—With zinc in dilute sulphuric acid, and zinc in a solution of sulphate of zinc, a deposit of zinc occurs.

Zinc Depositing Copper.—With zinc in dilute sulphuric acid, and brass in a solution of sulphate of copper, copper is deposited.

Bismuth Chloride of Antimony.—With bismuth in dilute hydrochloric acid, and antimony in chloride of antimony, no deposit of the latter takes place in twenty-four hours.

Iron and Chloride of Tin.—With iron in dilute hydrochloric acid, and tin in a solution of chloride of tin, no deposit of tin took place in eighteen hours.

Copper and Chloride of Antimony.—With copper in dilute hydrochloric acid, and antimony in chloride of antimony, or tin in chloride of tin, no deposit of antimony or tin took place in twenty hours.

12. *Observations upon Class of Instances No.* 4.—1st, It appears that negative as well as positive instances occur in this arrangement in common with the others; 2nd, that by using suitable metals and liquids, deposition may be effected more rapidly by this method than by the preceeding ones; 3rd, that the metal which receives the deposit derives its power from its contact with the other metal; 4th, that base metals in strong acids have the greatest power of causing a deposit upon the other metals, and noble metals the least; 5th, that the noble metals are more readily deposited than the base ones; and 6th, that thick and coherent deposit may be obtained.

In all the above instances, instead of using one vessel divided into two parts by a porous diaphragm, it will be found convenient to put one of the liquids in an unglazed earthenware porous cell, and immerse the cell in the other liquid (see vessel A, Fig. 13). In this case, either liquid may be in the outer vessel. This last arrangement (No. 4) is usually termed the "single cell" process.

13. **Depositing Arrangement No. 5.**—*Deposition by Separate Liquid.*—The next class of instances are those in which either of the foregoing arrangements, except the first, may be connected by wires with two pieces of similar metal immersed in a separate liquid. For instance:—

1st. *With Two Metals and One Liquid* (Fig. 12).—If we take a vessel A containing either dilute sulphuric acid or a solution of sulphate of copper, and immerse in it a piece of zinc B and copper C, with copper wires D and E attached to them, and either immerse the free ends of those wires in a separate solution of sulphate of copper F, or connect them with two pieces of copper immersed in that liquid, the piece of copper E in liquid F will dissolve, whilst the opposite piece D, connected with the zinc, will receive a deposit of copper.

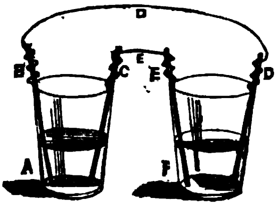

Fig. 12.

2nd. *With One Metal and Two Liquids.*—If we take a vessel A (Fig. 13) containing a porous cell B, with a neutral solution of sulphate of zinc C in the outer vessel, and dilute sulphuric acid D in the inner, and immerse two pieces of zinc E and F, with copper wires G and H attached, into D and C respectively, and immerse the ends of those wires in a separate solution of sulphate of copper I, the end of the wire H will dissolve, whilst that of G will receive a deposit of metallic copper.

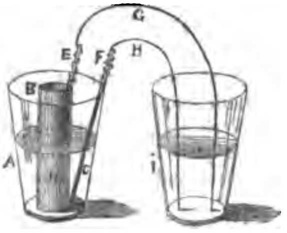

Fig. 13.

3rd. *With Two Metals and Two Liquids* ("single cell" arrangement, Fig. 13).—If we substitute a piece of copper for the piece of zinc F in the last-mentioned instance, and a solution of sulphate of copper for that of sulphate of zinc, similar effects will take place at the ends of the wires in the liquid I, except that the action will be much more rapid; but if in either of these three instances we use a solution of sulphate of zinc freely acidulated with sulphuric acid, instead of the solution of sulphate of copper I, and platinum wires in place of the copper ones to be immersed, neither of the pieces of platinum will dissolve or receive a metallic deposit.

14. *Remarks upon Class of Instances No. 5.*—In this class of instances the method or arrangement differs from the three preceding ones, simply by the wires which connect the two pieces of metal being cut in two, and its free ends either immersed in a separate liquid or connected with two pieces of metal dipping into that liquid. It is not necessary to have the depositing vessel perfectly separated; it may even be attached to the same piece of apparatus, provided the liquid in it is perfectly separated from the other liquids and metals. The pieces of metal in the separate liquid possess no power of deposition of themselves in that liquid, even if they were connected together, but derive their power of dissolving and receiving a deposit wholly from the other metals and liquids by means of the wires.

15. **Depositing Arrangement No. 6.**—*Deposition by Magnet and Coil* (Fig. 14).—We may produce deposition in the separate liquid by connecting the two pieces of immersed metal with any other source of depositing power—for instance, if a long copper wire A, covered with silk or cotton, is coiled upon a large bar of pure soft iron B, and its ends C and D are immersed in a solution of sulphate of copper E, and the poles of a powerful horse-shoe magnet F are brought in contact very many times with the end of the bar, and every time before removing the magnet from the bar one of the ends of the wire is taken out of the liquid, and replaced before returning the magnet, one end of the copper will slightly dissolve, and the other receive a thin copper deposit; but if each of the ends is allowed to remain constantly in the liquid, no such effects will occur.

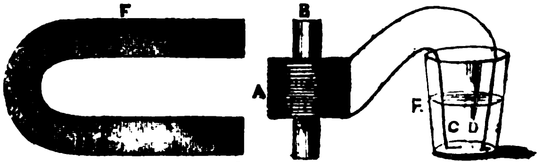

Fig. 14.

16. **Compound Depositing Arrangement No. 7.**—Any of the foregoing combinations of liquids and metals (except the first), or the magnetic arrangement, with or without separate depositing liquids, may be connected together in a *series* of any number, and may include each of the arrangements in the same series, or include any

number of depositing liquids, and deposition may be obtained either in the whole or in any portion of them at the same time; for instance, the vessel A (Fig. 15) contains a piece of zinc B, and copper C, immersed in dilute sulphuric acid; vessel D contains zinc E, in dilute sulphuric acid, and copper F, in a solution of sulphate of copper; vessel G contains a series of separate depositing liquids, consisting of solutions of sulphate of copper, connected together by bent pieces of copper; the extreme pieces being attached to zinc B and copper F; here deposition takes place upon every alternate piece of copper throughout the whole series, except that in vessel A.

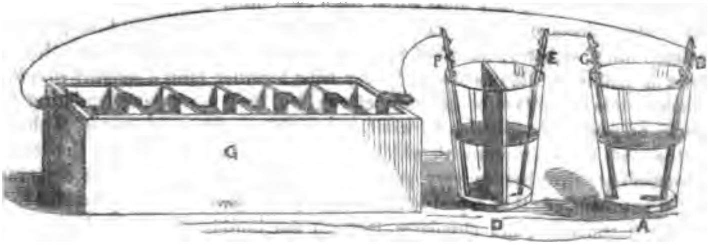

Fig. 15.

17. **General Observations.**—We may make the following general observations upon the whole of the foregoing facts:—1st, that negative as well as positive instances occur in all classes of facts of electro-deposition; 2nd, that almost any of the ordinary metals, both noble and base, may be deposited by each of the methods or arrangements described; 3rd, that the particular result of deposition or non-deposition occurring appears to depend chiefly upon the particular combination of liquids and metals, their arrangement and connections; 4th, that the size or shape of the containing vessels, the bulk or depths of the liquids, the size, form, or position of the metals, appear to exercise little or no influence upon the result; 5th, that in all cases of deposition there is a difference in *kind*, either of the metal, of the liquid, or of both; 6th, that in all such cases a metal dissolves in a liquid; for instance, in Arrangement No. 1, with a piece of iron immersed in a solution of sulphate of copper, a portion of the iron is dissolved as the copper is deposited; in Arrangement No. 2, with iron and copper together in a solution of sulphate of copper, the iron dissolves and the copper receives a deposit; in Arrangement No. 3, with copper in dilute sulphuric acid, and in a solution of sulphate of copper, the copper in the acid dissolves, whilst that in the metallic solution receives a deposit; in Arrangement No. 4, with zinc in dilute sulphuric acid, and copper in sulphate of copper, the former dissolves, whilst the latter receives a deposit; in Arrangements Nos. 5 and 6, one piece of metal in the separate depositing liquid dissolves, whilst the other receives a metallic deposit, and the same with the compound Arrangement No. 7; 7th, that in Arrangements Nos. 1 and 2, the same piece of metal which dissolves also receives a metallic deposit, and in Arrangements 3, 4, 5, 6, and 7, the pieces of metal which receive a deposit do not dissolve; 8th, that as a general rule in all methods, and in all solutions except alkaline metallic cyanides, zinc among common metals has the greatest, and platinum the least power of producing deposition; 9th, that zinc generally deposits metals most rapidly from their solutions, and most frequently in the state of a dark-coloured or black powder; and 10th, that among solutions of the salts of ordinary metals, those of the salts of noble

metals yield their metal most easily, and those of the base metals, zinc especially, with the greatest difficulty.

18. In looking over the foregoing instances, we also observe:—1st, that when several metals are used, they must either *touch* each other or be connected together by wires or other pieces of *metal;* 2nd, that when several liquids are used, they also must *touch* each other, either by means of a porous diaphragm, or otherwise; 3rd, that when a series of metals and liquids are used, they must together form a *complete circuit,* and all their points of contact be perfectly clean; 4th, that a separate depositing liquid possesses no power of deposition by itself, but derives its power by means of the wires from the other arrangements with which it is connected; and 5th, that the length of the connecting wire, has no very great influence on the result. These observations have led us to conclude that deposition is caused by some *force* which is generated in some part of the apparatus, and circulates through the liquids, metals, and wires, which compose the circuit.

19. **Principles.**—*Conditions of Electro-Deposition.*—From the simple *facts* of electro-deposition, and the general observations made upon them, we proceed to consider the *causes* of deposition, and the conditions or circumstances under which deposition occurs, in the following order:—

1st. *The Chemical Conditions.*—If we immerse a clean iron wire in a solution of nitrate of mercury, it receives a deposit of that metal; but if we immerse it in perfectly dry metallic mercury, it receives no deposit, because in the former case the necessary chemical conditions of deposition are present, whilst in the latter case they are absent.

2nd. *The Electrical Conditions.*—If we connect together a piece of iron and a piece of copper by means of a metal wire, and immerse them in a solution of sulphate of copper, the copper will receive a metallic deposit; but if we connect them together by a cord of gutta-percha or rod of glass, no deposit will take place, because in the former case all the electrical conditions are present, whilst in the latter case one of them, viz., a complete conducting circuit, is absent.

3rd. *The Thermic Conditions* remain unknown.

4th. *The Mechanical Conditions.*—If a piece of iron be immersed in a solution of sulphate of copper, it receives a copper deposit; but if a piece of platinum be so immersed it receives no such deposit, because, for one reason, in the former instance the mechanical conditions of attraction and repulsion at the dissolving and depositing surfaces are present, but in the latter they are absent.

5th. *The Mathematical Conditions.*—If we immerse two piece of carbon in fused *proto*-chloride of tin, and connect them with a voltaic battery, tin will be deposited; but if we immerse them in fused *bi*-chloride of tin no deposition will occur, because in the first instance all the mathematical conditions are present; the fluid salt contains *one* atom of chlorine for each atom of tin; whilst in the latter case one of them is absent, the salt contains *two* atoms of chlorine to one atom of tin, and, according to Faraday's law, "only those substances of the first order are directly decomposible which contain one atom of one of their elements for each atom of the other."

These several heads are capable of including all the known circumstances or conditions under which deposition occurs; and under the head of each of them will be given a few instances, both of deposition and of non-deposition, to illustrate the principle; and it would be advisable for the reader to try for himself most of the experiments given, in order to fix the principles more firmly in his memory.

20. **Chemical Conditions of Deposition.**—The first chemical condition to be observed is, that in every case of deposition the depositing liquid contains acid and basic elements, namely, a salt, the acid of which is to dissolve or combine with one metal, and its metal or base to be deposited upon the other.

1st. *Deposition by One Metal and One Liquid.*—With the first class of facts, if we immerse a piece of clean iron in a solution of nitrate of mercury, it will receive a deposit of that metal; but if we immerse it in mercury alone, it will receive no deposit; in the first instance an acid as well as a basic substance was present, and deposition took place; but in the second instance the metal or base alone was present, and no deposition occurred.

2nd. *With Two Metals and One Liquid.*—If zinc and platinum are immersed in mutual contact in a solution of nitrate of mercury, the platinum will receive a metallic deposit, but if they are immersed in pure dry mercury, no deposit will occur.

3rd. *With One Metal and Two Liquids.*—If we immerse one end of a platinum wire in a strong solution of cyanide of potassium, and its other end in a solution of nitrate of mercury, the two liquids being in mutual contact by means of a porous partition, the end in the metallic solution will soon receive a deposit of mercury; but if perfectly dry mercury is substituted for the nitrate solution, no such deposit will occur.

4th. *With Two Metals and Two Liquids.*—If we immerse zinc in dilute sulphuric acid, and platinum in a solution of nitrate of mercury, the two liquids touching each other by a porous partition, and the metals connected together by a wire, the platinum will quickly receive a deposit of mercury; but with dry mercury instead of the metallic solution, the platinum will not receive a deposit.

5th. *With a Separate Depositing Liquid.*—If we take two pieces of platinum wire, connect them, as already described (13), with either of the foregoing Arrangements, or with a magnet and coil (15), and immerse their free ends in a solution of nitrate of mercury, one of the wires will receive a deposit of mercury; but if the separate liquid consist only of dry mercury, no deposit will be obtained.

It is evident from these facts, that in every case where deposition occurs, the depositing liquid contains both acid and basic substances, and that without the presence of both no deposition takes place.

21. **Degrees of Chemical Affinity of Metals and Liquids.**—At the present point it is necessary to mention a few instances of the different degrees of chemical affinity manifested by different metals and liquids, that the reader may be able to understand their general chemical relations in electro-deposition more clearly:—

1st. If we immerse a piece of potassium in almost any liquid, very violent chemical action takes place, which is stronger in mineral and vegetable acids than in water or organic liquids; if we place a small piece of it upon water, violent chemical action occurs, the water is decomposed, heat is produced, gas is evolved and it takes fire, the metal melts and rolls about on the surface of the water, oxidates and dissolves.

2nd. If we immerse a piece of zinc in any of the strong mineral acids (sulphuric, hydrochloric, hydrofluoric, or nitric acids), strong chemical action takes place, gas is freely evolved, and the metal oxidates and dissolves; with solutions of the ordinary vegetable acids, *i.e*, oxalic, tartaric, citric, formic, and acetic acids, the same effects occur in a much weaker degree; but with water there is no visible decomposition, no gas evolved, nor any perceptible chemical action; these instances shew that potassium has a much stronger affinity for liquids than zinc, and that both potassium and zinc have a stronger affinity for acids, especially mineral ones, than for water.

3rd. If we immerse a piece of zinc successively in each of the ordinary mineral and vegetable acids diluted with water, it will be quickly dissolved, with evolution of hydrogen gas in nearly all of them; but if we immerse a piece of copper in those liquids, it will be quickly dissolved in only one of them, viz., nitric acid, and from this we conclude that copper has generally a much weaker affinity for acids than zinc.

4th. If we immerse either gold or platinum in any of the strong mineral or vegetable acids, or even in cold aqua regia, it will be quite unaffected in all of them, whilst copper would be rapidly acted upon by nitric acid or by aqua regia, and slowly by several of the others, thereby shewing that the affinity of gold or platinum for acids, is generally much weaker than that of copper.

From the foregoing, and many other instances that might be mentioned, we conclude that the general order of affinity of the metals for acids occurs in the following order, namely, potassium, zinc, copper, gold, and platinum. Hydrocyanic acid, and cyanogen appear to differ in one respect, in their chemical relations towards ordinary metals, from oxygen, chlorine, and the ordinary mineral and vegetable acids, in having a much stronger affinity for noble metals, and weaker for the base metals; this is probably one of the chief reasons for the extensive adoption of cyanogen compounds in electro-deposition; those compounds are highly suitable for the deposition of noble metals, because of the great affinity of cyanogen for those metals, but not, as some persons assert, for the deposition of many of the base metals, on account of its comparatively weak affinity for them.

22. Potassium is an *alkali* metal; zinc, cadmium, tin, lead, iron, cobalt, nickel, and copper, are *base* metals; and mercury, silver, gold, platinum, palladium, &c., are *noble* metals; and of these three classes, the alkali metals possess the strongest affinity for acids, base metals intermediate, and noble metals the least. The same order prevails in their degrees of depositing power; potassium and the alkali metals generally deposit nearly all metals from their solutions; zinc, and the base metals generally, deposit a smaller number; and gold, platinum, and the other noble metals deposit very few from their solutions; thus we perceive that those metals which have the strongest chemical affinity for acids, possess the greatest depositing power, and those which have the least affinity for acids, have also the least depositing power.

23. **Difference of Chemical Affinity Necessary to Deposition.**—The second chemical condition which we have to observe upon is, that in every case of *deposition* there is a *difference* of chemical affinity at the dissolving and receiving surfaces for the different elements of the liquid, and that the dissolving metal has a stronger affinity for the acid elements of the liquid than either the metal in solution or the receiving metal; for instance:—

1st. *With One Metal and One Liquid.*—If we immerse a piece of iron in a solution of sulphate of copper, a deposit takes place upon it, but if we immerse a piece of platinum in the liquid, it receives no deposit; in the first case, the iron having a stronger affinity for the sulphuric acid of the salt than copper, combines with it and dissolves, and the copper thereby set free from the acid is deposited upon the iron; whilst in the second case, platinum having a much weaker affinity for the acid than the copper, cannot separate the acid and copper, and therefore cannot cause deposition.

2nd. *With Two Metals and One Liquid.*—If we immerse copper and iron in mutual contact, in a solution of sulphate of copper, the iron dissolves, and deposition of copper takes place upon both metals; but if we immerse copper and platinum in mutual contact in this solution, no deposition occurs. In the first instance, the iron possessing a stronger chemical affinity for sulphuric acid than the copper, combines with it, and sets the copper free; by this action, a current of depositing force is generated, which circulates through the iron, liquid, and copper, at their points of contact, and causes the metal of the liquid to be deposited upon the piece of copper; but in the second case, neither the copper nor platinum possessing a stronger affinity for the acid of the salt than its associated metal, there is no copper set free, no current of depositing force generated, and consequently no deposition takes place.

3rd. *With One Metal and Two Liquids.*—If we immerse one end of a piece of copper in dilute sulphuric acid, and the other in a solution of sulphate of copper, the two liquids touching each other, copper will be deposited upon the end immersed in the metallic solution, whilst the other end will combine with the acid and dissolve; but if a piece of platinum or gold is substituted for the copper, neither of its ends will dissolve or receive a metallic deposit; in the first instance, the dilute sulphuric acid, having a stronger affinity for copper than a solution of sulphate of copper, combines with it, causes it to dissolve, develops a current of depositing force which circulates through the metals and liquids, and a deposit of copper is produced; whilst in the second instance, the platinum or gold having a weaker affinity for the acid of one liquid than copper for the acid of the other liquid, cannot separate the copper, or cause deposition.

4th. *With Two Metals and Two Liquids.*—If we immerse a piece of silver in a strong solution of cyanide of potassium, and a piece of copper in a solution of the double cyanide of copper and potassium, the liquids touching each other by a porous partition, and the metals mutually touching by a wire, the silver will dissolve, and the copper receive a metallic deposit; but if a piece of iron is substituted for the silver, no deposit will occur. In the first instance, the one solution has a stronger affinity for the silver, than the other has for the copper, consequently the former is dissolved, a current or depositing force is generated, and copper deposited; but in the second case, the one liquid has a weaker affinity for iron, than the other has for copper, and therefore no iron is dissolved, no depositing force generated, and no copper deposited.

5th. *With a Separate Depositing Liquid connected with any Source of Depositing Power.*—If we connect two pieces of silver with any of those sources of power, and immerse them in a solution of the double cyanide of silver and potassium, one piece will quickly dissolve, and the other receive a deposit of silver; but if pieces of iron are substituted for those of silver, neither will dissolve or receive a metallic deposit.

In every case where a separate depositing liquid is used, the two pieces of metal immersed in it have a *difference* of chemical affinity imparted to them by virtue of their connection with some arrangement which develops depositing force, and this difference of affinity is manifested most when the liquid has a strong affinity for the immersed metal, and least when it has a weak affinity for that metal; so in the first of the two immediately preceding instances, the liquid having a strong affinity for silver; allows this difference of affinity to be freely exercised at the immersed surfaces of the two pieces of metal, and consequently one dissolves, and the other receives a deposit; but in the second of these instances, the liquid having a very weak affinity for iron, does not admit of the exercise of this difference of affinity, and hence neither piece dissolves or receives a deposit. From these instances it is manifest that whenever deposition occurs, there is a difference of chemical affinity between the dissolving and receiving surfaces for the different elements of the liquid; that the dissolving metal has a stronger affinity for the acid elements than the receiving one; and that without this condition no deposition occurs.

24. It must be mentioned also that the metals which have the greatest difference in their degrees of affinity for acids, are those which evolve the greatest strength of depositing power; for instance—

1st. *With One Metal and One Liquid.*—If we immerse a piece of silver in a solution of terchloride of gold, it slowly becomes gilded, but if we immerse a piece of zinc in it, gold is almost instantaneously deposited; because, in the former case, the difference of affinity between gold and the immersed metal for the acid of the liquid is very much smaller than in the latter case.

2nd. *With Two Metals and One Liquid.*—If we immerse a piece of platinum and a piece of copper, in mutual contact, in a solution of nitrate of silver, the platinum will become silvered, but much more slowly than if iron or zinc were used in place of the copper, because there is a greater difference of affinity between platinum and iron or zinc for the acid of the liquid, than between platinum and copper; or, if we immerse a piece of zinc and a piece of platinum or platinized silver in dilute sulphuric acid, and connect them separately with two pieces of copper immersed in a separate solution of sulphate of copper, copper will be dissolved and deposited in the separate liquid more rapidly than if we used zinc and copper in place of zinc and platinum, and much more rapidly than if we used iron and copper; because the difference of affinity between zinc, platinum, or platinized silver for dilute sulphuric acid, is more than zinc and copper for that liquid, and much more than between iron and copper.

3rd. *With Two Metals and Two Liquids.*—If we immerse a piece of zinc in dilute sulphuric acid, and a piece of copper in a solution of sulphate of copper, the two liquids touching each other, and the two metals connected with two pieces of copper in a separate solution of sulphate of copper, the amount of metal dissolved and deposited in a given time in the separate liquid will be much smaller, than if we used zinc in dilute sulphuric acid, and platinum in strong nitric acid; because the difference of affinity between the two metals in the two liquids, in the first instance, is less than in the second instance.

25. **Acid and Basic Affinities Necessary.**—Chemical affinity differs not only in degree but also in kind; basic substances, such as metals, alkalies, alkaloids, and most metallic oxides, have a great tendency to combine with acids; whilst acid substances, such as the metalloids (oxygen, sulphur, chlorine, phosphorus, fluorine, &c.), mineral and vegetable acids, and some metallic oxides, tend to combine with bases. In a similar manner, the difference of affinity between the dissolving and receiving surfaces in electro-deposition is not wholly one of degree, but is also one of kind; the dissolving metal in a separate depositing liquid (13) acquires, by virtue of its connexion with some source of depositing power, an affinity for the *acid* elements of the liquid; whilst the receiving metal acquires, by the same means, an affinity of an opposite kind; for instance (Fig. 16), if a piece of platinum A and a piece of zinc B are immersed in dilute sulphuric acid C, some mercury D placed at the bottom of a separate solution of protosulphate of iron E, a piece of iron F immersed in this liquid and connected

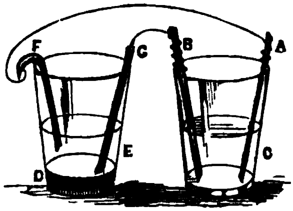

Fig. 16.

by a wire with the platinum, and the mercury connected by an iron or platinum wire G which is prevented from touching the liquid by a tube of glass or gutta-percha, the immersed piece of iron will exercise one kind of affinity, combine with the acid of the dissolved salt, and form a definite chemical compound (protosulphate of iron), containing one equivalent of iron and one equivalent of sulphuric acid; while the mercury will exercise an opposite kind of affinity, and combine with the metal or base of the salt, forming likewise a definite chemical compound (Fe Hg), containing one equivalent of iron and one of mercury. If a solution of sulphate of copper is substituted for that of sulphate of iron, and a piece of copper for the piece of iron; a similar definite compound of copper and sulphuric acid is formed at the dissolving plate, and of copper and mercury (Cu Hg) at the receiving metal.

These experiments prove in a most satisfactory manner that, in the act of deposition, the surface of the dissolving metal possesses one kind of affinity by virtue of which it tends to attract *acid* substances, and combine with them in definite proportions; and the surface of the receiving metal possesses an opposite kind of affinity, by virtue of which it tends to attract and combine with *basic* substances, also in definite proportions. Mercury is the only metal which has been observed to manifest this definite affinity at the receiving surface, probably because it is the only metal fluid at ordinary temperatures, fluidity being an essential condition of such affinity; but it is likely that other metals would also manifest this tendency, if kept in a melted state in contact with suitable fused salts, and properly acted upon by depositing force.

26. **Fluidity Essential to Electro-Deposition.**—The affinities of electro-deposition, like those of ordinary chemical action, require, generally speaking, one at least of the combining bodies to be in the liquid state; and they act, like them, wholly at insensible distances, being confined in their exercise to the immediate surfaces of mutual contact in the opposed substances, and the compound formed at those surfaces becomes diffused through the fluid masses by capillary cohesion and mechanical mixture. This affords a reasonable explanation why fluidity of the receiving metal is essential to the formation of definite compounds at its surface, as well as why fluidity of the metallic salt is essential to its decomposition, and for the formation of definite compounds at the dissolving surface. If chemical action took place at sensible and considerable distances, *i.e.*, throughout the whole mass of the opposed fluid bodies, combination would probably be in all cases violent and instantaneous; and if fluidity were not essential to combination, the substances deposited upon the receiving surface would probably, in most cases, enter into the mass of the receiving metal, and combine with it.

27. **Alternation and Circulation of Chemical Affinities Necessary.**—The next chemical condition to be observed upon is, that in every case of deposition the surfaces at which the acid and basic affinities are manifested *alternate* with each other in the circuit, and that the acid affinity *circulates* one way in the circuit, while the basic affinity *circulates* in the opposite direction; for instance—

1st. *With One Metal and One Liquid.*—If we immerse a piece of copper in a solution of double cyanide of silver and potassium, it becomes silvered; but if we immerse a piece of iron therein, it receives no deposit. In the first of these instances it is considered that, immediately upon the immersion of the metal, the superior affinity of copper for cyanogen over that of silver, causes it to combine with that substance, and set the silver free; at the same time, an immense number of minute currents of depositing force or chemical affinity are developed all over the immersed surface of the piece of copper, leaving it at innumerable minute points, passing a very small distance into the liquid, and re-entering the copper at numberless other points; and thus the affinities circulate, the copper dissolves, and receives a deposit simultaneously. In each of these atomic circuits as they are termed, acid affinity is exercised where the depositing force leaves the metal, and basic affinity where it re-enters it; but in the second instance, where iron is used, there is no circulation of those affinities, no dissolving of metal at one point, or deposition of it at another.

2nd. *With Two Metals and One Liquid.*—If we immerse a piece of iron and a piece of copper, in mutual contact, in a solution of sulphate of copper, a deposit of copper takes place upon the iron and upon the copper; but if we immerse a piece of gold in place of the iron, no deposit occurs upon either. In the first of these instances, in addition to the circulation of atomic currents of affinity all over the immersed surface of the iron, as already explained, and which cause it to dissolve and receive a deposit, there are separate and distinct currents of the same force circulating through the liquid, and the two metals by their points of mutual contact, cause the surface of the iron to combine with the acid, and that of the copper to receive a metallic deposit; but in the second case there is no circulation of affinities, and no solution of the gold or deposition of the copper.

3rd. *With One Metal and Two Liquids.*—If we immerse two pieces of silver, one in a solution of cyanide of potassium, and the other in a solution of double cyanide of silver and potassium, the two pieces being connected together by a wire, and the liquids touching each other by a porous partition, chemical affinities will circulate through the metals, wire, and liquids, and silver will be dissolved and deposited; but if we substitute pieces of iron for the pieces of silver, there will be no circulation of affinities and no deposition.

4th. *With Separate Depositing Liquids* (Fig. 17), consisting of solutions of sulphate of copper, with separate pairs of copper wires C D, E F, G H, immersed in them, and with end pieces of copper B and I, B being connected with a piece of zinc J immersed in dilute sulphuric acid, and I connected with a piece of copper A immersed in a solution of sulphate of copper, the two liquids being separated by a porous diaphragm K, chemical affinities will circulate in opposite directions through the whole of the circuit, every alternate piece of immersed metal, J, I, G, E, and C, will exercise one kind of affinity and dissolve, and every other alternate piece, A, B, D, F, and H, will exercise an opposite kind of affinity, and receive a deposit of copper. If in either of the foregoing instances, where deposition occurs, we break the continuity of the circuit, either by separating the metals from each other at their points

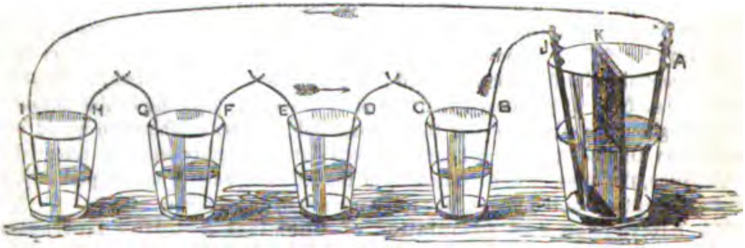

Fig. 17.

of contact, lifting them out of the liquid, or by cutting through the connecting wires, no deposition will occur; but if we immerse the free ends of the divided wire in a suitable liquid, such as a solution of sulphate of copper, if the wires are of copper, deposition will immediately recommence throughout the circuit.

28. A consideration of such facts as these, leads us to conclude that the process which causes every alternate metal in a series to combine with *acids* and dissolve; and every other alternate metal in the circuit either to combine with bases, or receive a deposit, are of a chemical character, and *circulate* in opposite directions through the circuit, and has led to the application of the term "current affinity," to designate the depositing force, when viewed only in a *chemical* aspect.

29. Two or any other *even* number of vessels containing combinations of liquids and metals, each similar, and capable of generating current affinity, may be so arranged in a complete conducting circuit, that no current affinity will circulate or deposition occur; for instance, if we take two separate vessels A and B (Figure 18), each containing dilute sulphuric acid, and a separate piece of zinc Z, and silver (S), and connect them together thus, zinc, silver, silver, zinc, no depositing power will be manifested if we immerse the free ends of their copper wires C C in a separate solution of sulphate of copper D; but if they are connected thus, zinc, silver, zinc, silver (Figure 19), and the copper wires immersed as before, current affinity will circulate, and deposition will proceed in the separate liquid. In the first of these cases the affinities set in motion by the metals and liquid in the vessel A are opposite in direction to those generated in vessel B, and the two arrangements, being equal in power, exactly neutralize each other, preventing the currents of affinity and their effects; but in the second case the direction of the affinities evolved by the vessel A coincide with that of those from vessel B, the currents circulate, and deposition is effected. In the case of an unequal portion of the metals of a series being connected the opposite way, those which are wrongly connected will neutralize and be neutralized by an equal number of the remainder, provided that all the pairs of metals andt he liquids are similar; for instance, if three out of twelve are wrongly connected, they will neutralize the power of three more, and only the remaining six will act in the desired direction.

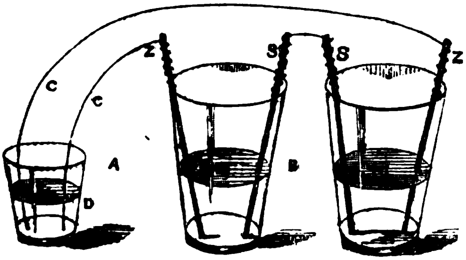

Fig. 18.

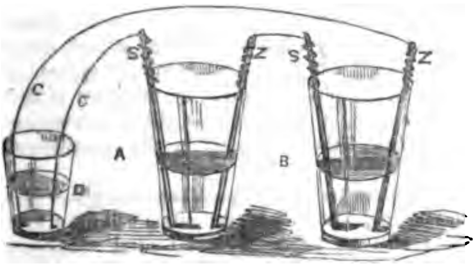

Fig. 19.

30. During the act of deposition, a salt is generally formed at the dissolving surface by the union of the metal with the acid elements of the liquid, which is dis-

solved in the liquid; at the same time the acid, which combines with the dissolving surface, is generally set free at the receiving surface by the deposition of the metal; for instance—

1st. *With One Metal and One Liquid.*—When iron coats itself with mercury by simple immersion in a solution of nitrate of mercury, nitrate of iron is formed by the union of the iron with the nitric acid or of the nitrate of mercury, and nitric acid is at the same time set free by the deposition of the mercury.

2nd. *With Two Metals and One Liquid.*—When copper receives a deposit of copper by immersion, in contact with a piece of iron in a solution of sulphate of copper, sulphate of iron is formed at the immersed surface of the iron, by the union of the sulphuric acid, or the sulphate copper salt, with the iron; at the same time sulphuric acid is set free at the copper surface by the deposition of the copper.

3rd. *With One Metal and Two Liquids.*—When copper receives a deposit of copper in a solution of sulphate of copper, by connection with another piece of copper immersed in dilute sulphuric acid, the two liquids touching each other by means of a porous partition or otherwise, sulphate of copper is formed at the surface of the metal in the dilute acid, by the union of the copper with the acid, and, at the same time, sulphuric acid is set free at the surface of the other piece by the deposition of the copper.

4th. *Silver.*—When silver or any other metal receives a coating of silver in a solution of double cyanide of silver and potassium, by connection with a piece of zinc in dilute sulphuric acid, the two liquids being separated by a porous diaphragm, sulphate of zinc is formed at the surface of the zinc, by the union of the acid and zinc, and cyanogen (a substance of acid character) is at the same time set free at the receiving surface, by the deposition of the silver.

5th. *With a Separate Depositing Liquid,* connected with any source of current affinity—for instance, when two silver plates, immersed in a solution of the double cyanide of silver and potassium, are connected by wires with a piece of zinc, and a piece of copper is immersed in dilute sulphuric acid in a separate vessel; cyanide of silver is formed at the surface of one of the pieces of silver by the union of that metal with the cyanogen of the liquid; and, at the same time, either cyanogen or hydro-cyanic acid is set free at the surface of the other piece by the deposition of the silver.

31. **Proper Proportion of Free Acid in the Depositing Liquid.**—If a solution contains a large excess of uncombined acid, metallic deposition will not always occur; for instance, if two pieces of zinc are immersed in a neutral solution of sulphate of zinc, and connected by wires with another piece of zinc, and a piece of silver is immersed in dilute sulphuric acid, in a separate vessel, one piece of zinc will dissolve and the other receive a deposit of metal; but if a rather large quantity of sulphuric acid is added to the depositing liquid, no deposit of zinc will occur. In the same manner, if we connect two pieces of silver, immersed in a strong solution of cyanide of potassium, with the zinc and silver in dilute sulphuric acid, as just described, one of the pieces of silver will combine with the cyanogen of the cyanide of potassium, and form cyanide of silver, which will combine with a portion of the remaining cyanide and then dissolve; but the other piece of silver will not receive a deposit of silver, until the remaining uncombined cyanide of potassium has decreased to a certain proportion by the working of the process. If, on the other hand, a depositing solution contains no *free* combining substance, deposition will either

proceed very slowly, or be entirely stopped, in consequence of an insoluble salt being formed upon the surface of the dissolving metal, and impeding the action; for instance, when two silver plates, immersed in a solution of double cyanide of silver and potassium, are connected with some source of depositing power, one of the plates will receive a deposit of silver, whilst the other will gradually become covered with a white layer of insoluble cyanide of silver, which impedes and eventually stops deposition.

32. **Necessity of a Proper Proportion of Water.**—If a depositing solution is diluted with water to a very large extent, deposition will progress very slowly, but if, on the other hand, it contains insufficient water, crystals of metallic salts will collect upon the dissolving metal and gradually stop the action; for instance, if two pieces of copper, immersed in a *saturated* solution of sulphate of copper containing free acid are connected with a piece of zinc, and a piece of silver immersed in dilute sulphuric acid in a separate vessel, one piece will receive a deposit of copper, whilst the other will slowly dissolve and gradually become covered with crystals of sulphate of copper, first at its lower part and then at the edges, which will gradually stop the action.

33. All the foregoing chemical facts prove that chemical affinity plays a very important part in the phenomena of electro-deposition.

34. **Electrical Conditions of Deposition—Positive and Negative Substances Necessary.**—The first electrical condition to be observed is, that in every case of deposition the liquid contains both substances of an electro-positive and of an electro-negative character; metals and alkalies are electro-positive, and metalloids (oxygen, sulphur, chlorine, iodine, bromine, &c.) and acids are electro-negative; cyanogen is also electro-negative.

1st. *With One Metal and One Liquid.*—In the first instance, if we immerse a piece of copper in a solution of nitrate of mercury, deposition occurs, mercury being deposited, but if we immerse it in dry mercury, there is no deposition; in the former case the liquid contains both electro-positive mercury and negative nitric acid, but in the latter case it only contains the positive mercury.

2nd. *With Two Metals and One Liquid.*—Immerse zinc and platinum in mutual contact in a solution of nitrate of mercury, the platinum receives a deposit; but if we immerse them in dry mercury, it receives no deposit.

3rd. *With One Metal and Two Liquids.*—If one end of a platinum wire is immersed in a solution of cyanide of potassium, and the other end in a solution of nitrate of mercury, the two liquids touching each other by a porous partition, the end in the mercurial solution will receive a metallic deposit; but if dry mercury be substituted for the nitrate solution, no deposition will occur.

4th. *With Two Metals and Two Liquids.*—If we immerse zinc in dilute sulphuric acid, and platinum in a solution of nitrate of mercury, the metals touching each other, and the liquids separated by a porous partition, the platinum receives a mercurial deposit; but if dry mercury is substituted for the nitrate solution, it receives no deposit.

5th. *With a Separate Depositing Liquid.*—If we immerse two platinum wires in a solution of nitrate of mercury, and connect them with any source of depositing power, one of the wires will receive a metallic deposit; but if we use dry mercury instead of the nitrate solution, there will be no deposit.

These and many other instances prove that unless the depositing liquid contains both electro-positive and electro-negative substances, no deposition occurs.

35. **Electric Polarity of the Dissolving and Receiving Metals.**—The second electrical condition to be observed upon is, that in every case of deposition there is an electrical difference between the dissolving and receiving metals, and that the former is always electro-positive, the latter being electro-negative, relatively to each other; the dissolving metal, consequently, has the strongest electrical attractions for the electro-negative or acid elements of the liquid, and the receiving metal has the strongest electrical attraction for the electro-positive or metallic elements; for instance—

1st. *With One Metal and One Liquid.*—Iron in a solution of sulphate of copper, being electro-positive to the copper of the salt, has a stronger electric attraction for the acid or electro-negative elements than the copper, and combines with them in setting the copper free; but in a solution of sulphate of zinc, iron being electro-negative to the zinc of the salt, has a weaker attraction for the acid than the zinc, and therefore does not combine with or set the zinc free.

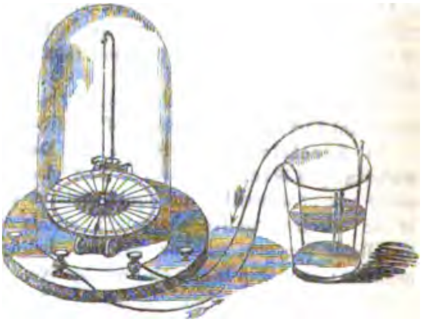

Fig. 20.

2nd. *Two Metals and One Liquid.* If we immerse a piece of iron and a piece of copper in a solution of sulphate of copper, and connect them by wires with a galvanometer (Fig. 20), the copper will receive a deposit, and the needles N of the instrument will be strongly deflected in such a direction as to indicate that the iron is positive, and the copper negative; but if a piece of iron and a piece of zinc are immersed in a solution of sulphate of zinc, and connected with the instrument, no deposit will take place upon either metal, and scarcely any deflection of the needles will be produced.

3rd. *With One Metal and Two Liquids.*—If one piece of copper is immersed in dilute sulphuric acid, and another in a neutral solution of sulphate of copper, the two liquids touching each other by a porous partition, and the pieces of copper connected by wires with the galvanometer, deposition will take place upon the piece of copper in the metallic solution, and the instrument will indicate, by the direction of the deflection of its needles, that the dissolving piece of metal is positive, and the receiving piece negative; but if we substitute two pieces of platinum for the pieces of copper, no deposition of copper will occur, and scarcely any difference of electric condition between the two pieces of metal will be indicated by the galvanometer.

4th. *With Two Metals and Two Liquids.*—If a piece of zinc is immersed in dilute sulphuric acid, and a piece of copper in a solution of sulphate of copper, the two liquids being separated by a porous partition, and the metals connected with the galvanometer, deposition will take place freely upon the copper, and the needles of the instrument will be powerfully deflected, indicating, by the amount and direction of their movement, the zinc to be strongly positive and the copper negative; but if a piece of platinum is substituted for the zinc, there will be no deposition, and scarcely any deflection of the needles.

5th. *With a Separate Depositing Liquid.*—If we immerse two pieces of silver in a solution of the double cyanide of silver and potassium, and connect them with any source of depositing power, and interpose a galvanometer in the circuit, deposition of silver will occur, and the needles will be strongly deflected in such a direction as to indicate the dissolving piece of silver to be positive, and the receiving piece negative; but if we substitute two pieces of iron for the pieces of silver, there will be scarcely any deposition of silver, and very little deflection of the needles, the receiving piece being feebly negative. From these and many other similar cases, we conclude that in every case where deposition occurs, the dissolving metal is electro-positive, and the receiving metal electro-negative, relatively to each other, and that the former has the strongest electric attraction for the negative elements of the liquid, and the latter for the basic or metallic element. In all electric phenomena, positive substances repel positive and attract negative, and negative substances repel negative and attract positive.

36. Alternation and Circulation of Electro-Polarities Necessary.—The third electric condition is, that in every case of deposition, the positive and negative surfaces, or metals, *alternate* with each other in the circuit, and electric forces *circulate* through the circuit; for instance—

1st. *With One Metal and One Liquid.*—When a piece of iron is immersed in a solution of sulphate of copper, innumerable minute electric currents are generated upon the surface of the metal, and circulate to a very minute depth within the opposed surface of the liquid, while the positive electricity passing out of innumerable points of the iron into the solution causes it to dissolve—pass through the solution, re-enter the iron at innumerable other points, and deposit the copper; but when a piece of gold is immersed in this solution, there are no currents of electricity generated, and the gold is neither dissolved nor does it receive a deposit.

2nd. *With Two Metals and One Liquid.*—When a piece of zinc and a piece of silver are immersed in mutual contact in a solution of nitrate of silver, the zinc dissolves and the silver receives a deposit, and an electric current is developed which circulates through the metals and liquids, and may be rendered further evident by connecting the metals with a galvanometer (Fig. 20); the zinc is positive and the silver negative.

3rd. *With One Metal and Two Liquids.*—When two pieces of copper are immersed, one in dilute sulphuric acid, and the other in a solution of sulphate of copper, the two liquids touching each other through a porous diaphragm, and the pieces of copper connected with a galvanometer, an electric current circulates through the circuit, the piece of copper in the acid is positive and dissolves, and the piece in the metallic solution is negative and receives a deposit.

4th. *With Two Metals and Two Liquids.*—When a piece of zinc is immersed in dilute sulphuric acid, and a piece of silver in a solution of double cyanide of silver and potassium, and the two are connected with a galvanometer, the two liquids touching each other by a porous partition, electricity circulates through the circuit, the zinc is positive and dissolves, and the silver is negative and receives a deposit.

5th. *With a Separate Depositing Liquid.*—When two pieces of antimony immersed in the ordinary chloride of antimony, are connected with any source of electricity, one piece becomes positive and dissolves, and the other negative and receives a deposit, and an electric current circulates through the circuit, as may easily be proved by the galvanometer, as in the foregoing instances.

6th. *With a Series of Depositing Liquids.*—If a series of depositing vessels (Figs. 15 and 17), containing solutions of sulphate of copper, and pieces of copper, are connected by their extreme pieces with a sheet of zinc, and a sheet of copper immersed in a solution of sulphate of copper, every alternate piece of metal in the series will be electro-positive and dissolve, and every other alternate piece electro-negative and receive a deposit, and a current of electricity will circulate through the whole series.

37. **Electrical Conducting Circuit Necessary.**—In every case where deposition is proceeding, the whole of the circuit is capable of conducting voltaic electricity; and this is one important condition of the result, for if in any such case we interpose an imperfect electric conductor in the circuit, such as a long iron wire, or a short column of water, the process will be greatly impeded, and if we interpose a non-conductor of electricity, such as a rod of glass or of gutta-percha, or allow the least film of air to break the continuity of the circuit, deposition will be completely arrested.

38. **Electric Conductivity.**—The following is the general order of the conductivity of metals and alloys for voltaic electricity at 60° Fah., beginning with those which conduct most freely, viz., silver, copper, gold, cadmium, zinc, brass, tin, palladium, iron, steel, lead, platinum, german silver, antimony, mercury, bismuth, potassium. The order is somewhat different at other temperatures.

39. **Direction of the Electric Currents.**—In every case where a current of electricity is developed by the mutual contact of liquids and metals, or where it merely passes through them, as in a separate depositing vessel, the current of *positive* electricity invariably passes from the positive or dissolving metal, *through the liquid*, to the negative or receiving one; and the negative electricity passes similarly in the opposite direction. When we speak of "*the current*," without stating which is meant,—the positive or negative electricity,—it is always intended, for the sake of simplicity of expression, to indicate the *positive* electricity; when we speak of the positive *metal* or *plate*, the metal which is positive and dissolves is meant; but when the positive *pole* is mentioned, the metal from which the positive electricity proceeds out of the arrangement or apparatus into the wires, and which is invariably the negative or receiving metal, is intended; for instance, if a piece of zinc and a piece of silver or copper are immersed in dilute sulphuric acid, the zinc is the *negative pole* and the *positive plate*, whilst the copper or silver is the *positive pole* and the *negative plate*.

40. In a separate depositing vessel it is the dissolving metal which is called the positive plate, because it corresponds to the zinc or dissolving plate of the battery, while the receiving metal is called the negative plate; the term pole is also sometimes applied to those plates, but in an irregular manner.

41. **Electrical Decomposition of Liquids.**—In all cases of electro-deposition, the elements of the liquids are split asunder by electric action at the surfaces of the metals; the electro-negative elements, such as metalloids and acids, either combine with, or are set free at the surface of the dissolving or positive metal, and the electro-positive elements, such as metals and alkalies, either combine with, or are set free or deposited, at the surface of the receiving or negative metal; for instance, if a piece of silver and a piece of copper are immersed in a solution of sulphate of copper, and a piece of zinc and a piece of platinum immersed in dilute sulphuric acid, the silver connected with the zinc by one wire, and the copper with the platinum by another wire, the *negative* elements of the liquid, namely, the sulphuric acid of the sulphate of copper solution, will be split from its associated copper, and will *combine* with the positive metal, the copper, causing it to dissolve in the liquid; while the *positive* element of the liquid, namely, the copper of the salt, will be deposited at the surface of the negative or receiving metal, the silver, but will *not combine* with it; but if we substitute a piece of platinum for the piece of copper, and mercury for the silver (Fig. 16), the effects

will be reversed, the acid or negative element will collect around the positive platinum, but will *not combine* with it, whilst the positive element of the liquid, the copper, will be deposited and *combine* with the negative mercury. Fused salts yield the same substances by electric decomposition as the same salts yield dissolved in water.

42. **Electrical Terms in Deposition.**—For the more clear remembrance of the different parts of the circuit and of the direction of the electric forces, and for the better understanding of the action of the currents, Faraday has proposed the following terms, which have come into general use:—The liquid undergoing decomposition he terms an "*electrolyte*," from two Greek words, "electron," meaning "electric," and "luo," to "set free;" the act of electric decomposition he terms "*electrolysis*;" the metallic or other surfaces at which the electric forces enter and leave a liquid he terms "*electrodes*," from two Greek words, "electron" and "odos," meaning a "way;" the positive electrode, or that point at which the positive electricity enters a liquid, is termed "*anode*," from two Greek words, "ana," meaning "upwards," and "odos," a "way,"—the way in which the sun rises; and the negative electrode, or that by which the positive electricity leaves a liquid, is termed "*cathode*," from two Greek words, "cata," meaning "downwards," and "odos," a "way,"—the way in which the sun sets; the elements of the liquid set free by electrolysis he terms "*ions*," from a Greek word meaning "going;" those which combine with, or are set free at the anode, are termed "*anions*;" and those which combine with, or are set free at the cathode, are termed "*cations*."

43. **Anions and Cations.**—Under the head of Anions may be classed—oxygen, fluorine, chlorine, bromine, iodine, and cyanogen, probably also sulphocyanogen, also the various mineral acids. Cations include—hydrogen (and ammonium), the alkali metals, magnesium, manganese, arsenic, antimony, bismuth, zinc, cadmium, tin, lead, iron, cobalt, nickel, copper, mercury, silver, gold, platinum, palladium, and the salifiable bases.

44. **Electro-chemical Scale.**—The various elementary substances have been arranged by Berzelius according to their relative degrees of positive and negative electro-chemical character, in a table or scale like the accompanying one, commencing with those substances possessing the strongest electro-positive properties, and ending with those of the strongest electro-negative properties:—

POSITIVE END.

NAME.	SYMBOL.
Potassium	K.
Sodium	Na.
Lithium	L.
Barium	Ba.
Strontium	Sr.
Calcium	Ca.
Magnesium	Mg.
Glucinum	G.
Yttrium	Y.
Aluminium	Al.
Zirconium	Zr.
Thorium	Th.
Cadmium	Cd.
Manganese	Mn.
Zinc	Zn.
Iron	Fe.
Nickel	Ni.
Cobalt	Co.

NAME.	SYMBOL.
Cerium	Ce.
Lead	Pb.
Tin	Sn.
Bismuth	Bi.
Uranium	U.
Copper	Cu.
Silver	Ag.
Mercury	Hg.
Palladium	Pd.
Rhodium	R.
Platinum	Pt.
Iridium	Ir.
Osmium	Os.
Gold	Au.
Hydrogen	H.
Silicium	Si.
Titanium	Tit.
Tantalum	Ta.

NAME.	SYMBOL.
Tellurium	Te.
Antimony	Sb.
Carbon	C.
Boron	B.
Tungsten	W.
Molybdenum	Mo.
Vanadium	Va.
Chromium	Cr.
Arsenic	As.
Phosphorus	P.
Selenium	Se.
Iodine	I.
Bromine	Br.
Chlorine	Cl.
Fluorine	Fl.
Nitrogen	N.
Sulphur	S.
Oxygen	O.

NEGATIVE END.

It will be observed that the division indicated in the above table between gold and hydrogen is, in a great measure, an arbitrary one; useful to assist one's memory in recollecting the general electro-chemical character of the substances, but not really existing in nature; for instance, sulphur and chlorine, two of the most negative of substances, must be viewed as positive in relation to oxygen; a still more negative substance when combined with that element, as hyposulphurous or hypochlorous acid, but negative in relation to arsenic, hydrogen, zinc, potassium, when combined with those elements, in the various metallic sulphides and chlorides; in fact, each substance throughout the scale may be viewed as both positive and negative,—positive in relation to those below it, and negative in relation to those above it; those of the upper end being strongly positive and feebly negative, and those of the lower end strongly negative and weakly positive. It has been objected that sulphur and nitrogen occupy a position too near the negative end of the scale, they being generally less negative than chlorine and fluorine; also that hydrogen should be placed higher up in the positive division.

45. A consideration of all the foregoing facts leads us to conclude, that current electricity acts a most important part in all the phenomena of electro-deposition.

46. **Thermic Conditions.**—Under this head comparatively little can be said, because it is that portion of the subject which has been the least investigated; but it is highly probable that, as heat is generally evolved by the chemical combination of metals with metalloids or with acids, there exist thermic as well as electric and chemical conditions of deposition. In a series of experiments with two plates of antimony immersed in a conducting liquid, the two plates being maintained at different temperatures, and numerous liquids being tried, a weak current of electricity was developed, which passed from the hot metal through the liquid to the cold one, the hot metal thus being positive: in all cases except with liquids containing uncombined nitric acid.

47. **Influence of Temperature on the Depositing Liquid.**—The strength of affinity between the different elements of a liquid undergoing electrolysis, varies with the temperature of the liquid; being almost invariably diminished by elevation of temperature. Rise of temperature increases the electric conductibility of an electrolyte, and decreases that of the metal plates immersed in it; but the decrease of conductibility of the latter is small in proportion, at moderate elevations of temperature, compared with the increase of the former; consequently the general effect of heating a depositing liquid is to increase the rapidity of deposition.

48. We have repeatedly observed, that with some solutions used at a high temperature for depositing, if the cathode was immersed in the liquid at the ordinary atmospheric temperature, and the liquid then heated to the desired point, no conduction or deposition took place; nor did it occur if the receiving metal was taken out, washed in cold water, and re-immersed; but if the temperature of the liquid was first raised, and then the cold cathode suddenly immersed, deposition took place freely, and the liquid might be cooled down many degrees without stopping the action. In coating iron with tin in some solutions, if the iron was immersed before heating the liquid, no deposition took place even at 150° Fah.; but if the liquid was first heated, deposition occurred below 100° Fah.

49. **Influence of Light upon Deposition.**—Light appears to exercise much less influence upon electro-deposition than heat; in some cases, however, where the elements of a depositing liquid are held together by unstable affinities, it decomposes

the liquid and renders it unfit for deposition; for instance, a solution formed by dissolving hyposulphate of silver in a solution of hyposulphite of soda, has a tendency to be decomposed in this way.

50.—**Dynamic or Mechanical Conditions.**—The various phenomena occurring in a liquid undergoing electrolysis, may be viewed, in a mechanical or dynamic aspect, as a series of minute movements (attractions and repulsions) occurring between the various particles of matter composing the opposed surfaces of the liquids and of the metals immersed in them; for instance, if we immerse a piece of zinc in a solution of sulphate of copper and connect it with some mercury in the same liquid, by a platinum wire, protected from the solution by a tube of glass or gutta-percha, the particles composing the surface of the zinc, being all electro-positive, will tend to repel each other, and the particles of the liquid surface in contact with it, being rendered electro-negative, will also tend to repel each other, whilst the particles of acid near, being electro-negative, will attract the particles of zinc, which are electro-positive, and the two will combine together and form a salt; at the same time, the particles of the liquid surface in contact with the mercury, being made electro-positive, will tend to repel each other; while the particles of the opposed mercury surface, being rendered electro-negative, will also tend to repel each other, whilst the particles of the mercury, being electro-negative, and the contiguous particles of copper in the liquid being electro-positive, the two will combine together and form an alloy. The deposition of copper upon the *zinc* in this case must be wholly disregarded, because it is quite a separate and distinct phenomenon.

To put this in a clearer form, suppose (Fig. 21) the vertical row of particles Cu, Cu, Cu, Cu, to represent the copper anode of a sulphate of copper depositing liquid, and the row of particles Hg, Hg, Hg, Hg, the mercury cathode, Pt, Pt, being the connecting wires from the battery, and the double row representing the particles of acid SO^4, and copper C'u, composing the intervening liquid; the particles of the anode surface, being all electro-positive, tend to repel each other; and the contiguous particles of Cu and SO^4, being all negative, also tend to repel each other, whilst the particles of the copper anode, being positive, attract the nearest particles of negative acid, and combine with them and form a salt; at the same time, the particles of C'u and SO^4 nearest the mercury, being all positive, tend to repel each other, whilst the contiguous particles of mercury being negative, and the copper in the liquid being positive, attract and combine with each other and form an alloy. By this combination of simultaneous movements, the copper anode dissolves, and the mercury (or any other conducting substance which forms the cathode) receives a deposit, and the particles of copper of the liquid are gradually removed and replaced by those from the anode.

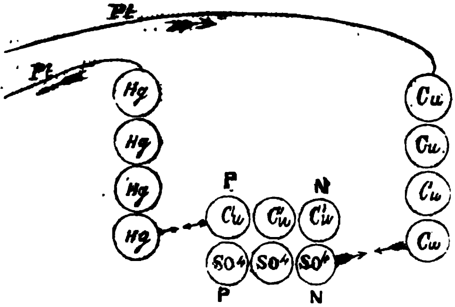

Fig. 21.

51. These attractions and repulsions like ordinary chemical actions, are all supposed

to take place at insensible distances, at the mutually opposed surfaces of the liquids and metals, and not to extend into their masses, except so far as they are mixed with each other by capillary attraction or ordinary mechanical motion, and can therefore only take place where one or both of the substances are in a liquid state; if it were otherwise, the combinations and decompositions of the whole masses would probably occur instantaneously.

52. In addition to those minute and invisible movements of the particles, there are other and sometimes visible movements produced by capillary attraction and by difference of specific gravity in the liquids; for instance, the salt formed at the anode, if it is soluble in the liquid, is dissolved and gradually diffused through it by capillary attraction or adhesion, whilst from its greater specific gravity than the remainder of the liquid when dissolved, it tends to sink towards the bottom; at the same time, the acid set free at the cathode is likewise gradually diffused through the liquid by similar means, and from its less specific gravity tends to rise to the surface. These movements are of general occurrence during deposition, and in some solutions, especially if they are very dense and possess a colour, are plainly visible to the unassisted eye; and their occurrence explains why the substances set free by deposition are not instantaneously transferred from one electrode to the other, but occupy, especially in dense liquids and electrodes far asunder, a considerable period of time in their transference; it also explains why, if depositing solutions are not occasionally stirred, their upper portions become exhausted of metal, whilst their lower parts become deficient of acid. Motion of the cathode is generally considered necessary to make the deposited metal harder.

53. **Position of the Electrodes.**—The position of the electrodes has a considerable influence upon the phenomena of electro-deposition. For instance—1st, If the two electrodes in a depositing liquid are horizontal, with the anode above and the cathode below, the salt formed at the anode will, by virtue of its greater specific gravity, sink in the liquid, whilst the acid set free at the cathode will, by its less specific gravity, rise upwards, and thus the anode will be constantly supplied with fresh uncombined acid, the cathode will receive a constant supply of metallic salt, and deposition will continue without interruption. 2nd, If the two electrodes are vertical in the liquid, similar differences of specific gravity will cause the lower part of the liquid to become saturated with metallic salt, and its upper part to consist of free acid mixed with the water; in consequence of this, the current of electricity will almost wholly pass from the upper part of the anode diagonally downwards, through the liquid to the lower part of the cathode, and thus the upper part of the anode will dissolve rapidly, whilst its lower part will dissolve but slowly, and the cathode will receive a rapid deposit at its lower part and but very little at its upper part. In this position, vertical lines, and even deep grooves, are sometimes produced in the deposit (especially if the position of the cathode is slightly overhanging), by the ascent of streams of the lighter acid liquid from which the metal has been exhausted by deposition; if the solution is nearly a saturated one, and has been freely worked without stirring or disturbance for some time, crystals of the metallic salt are apt to form all over the lower part of the anode, which will be dissolved very rapidly at the surface of the liquid, and appear as if cut by a knife; in addition to these effects, if the solution is a very deep one, with much free acid, two independent currents of electricity will be developed, one in each electrode, by the unequal action of the two different strata of liquid upon their upper and lower parts. An instance of this will be found in "One Metal in Two Liquids" (9),

in which these currents leave them at their upper parts, pass down through the liquid, and re-enter them at their lower extremities.

54. **Form of the Electrodes.**—If either of the electrodes be of an irregular form, or have unequal projections or hollows, the anode will dissolve most freely, and the cathode receive the greatest deposit of metal at those parts at which they are nearest each other, and least in the hollows and more distant parts. If the surface of the cathode be rough, it greatly increases the tendency of the deposit to become crystalline.

55. **Mathematical Conditions.**—*Definite Chemical Action.*—In the combination of different elementary and compound substances with each other, by ordinary chemical affinity, it has been observed, and accurately proved by analysis, that their combinations invariably take place in certain definite proportions, or in very simple multiples of those proportions; and as in the first of these cases it is inferred that their combinations with each other occur, one atom with one atom, the numbers which represent those simple proportions represent also the relative weights of those atoms to each other. The following table contains the names, symbols, and atomic weights of nearly all the simple or elementary substances:—

Name.	Symbol.	Atomic weight.	Name.	Symbol.	Atomic weight.	Name.	Symbol.	Atomic weight.
Hydrogen	H	1·0	Cobalt	Co	29·5	Uranium	U	60·0
Beryllium	Be	4·7	Nickel	Ni	29·6	Tellurium	Te	64·2
Carbon	C	6·0	Copper	Cu	31·7	Barium	Ba	68·5
Lithium	Li	6·5	Phosphorus	P	32·0	Vanadium	Va	68·6
Oxygen	O	8·0	Zinc	Zn	32·6	Arsenic	As	75·0
Boron	B	10·9	Chlorine	Cl	35·5	Bromine	Br	80·0
Magnesium	Mg	12·2	Potassium	K	39·2	Tungsten	W	95·0
Aluminium	Al	13·7	Selenium	Se	39·5	Platinum	Pt	98·7
Nitrogen	N	14·0	Strontium	Sr	40·8	Iridium	Ir	99·0
Sulphur	S	16·0	Molybdenum	Mo	46·0	Osmium	Os	99·6
Fluorine	Fl	18·9	Lanthanum	La	47·0	Mercury	Hg	100·0
Calcium	Ca	20·0	Cerium	Ce	47·0	Lead	Pb	103·7
Silicium	Si	21·3	Didymium	D	50·0	Silver	Ag	108·1
Zirconium	Zr	22·4	Rhodium	R	52·2	Iodine	I	127·1
Sodium	Na	23·0	Ruthenium	Ru	52·2	Antimony	Sb	129·0
Titanium	Ti	25·0	Palladium	Pd	53·3	Tantalum	Ta	184·0
Chromium	Cr	26·7	Cadmium	Cd	56·0	Gold	Au	197·0
Maganese	Mn	27·6	Tin	Sn	59·0	Bismuth	Bi	213·0
Iron	Fe	28·0	Thorium	Th	59·6			

56. As there are a number of compound substances used in electro-deposition, such as sulphuric acid, cyanide of potassium, &c., and it will be useful to the practical depositor to know their combining proportions in making the different salts, used in the art, we have selected those which are likely to be required, and give their names, symbols, and atomic weights or combining proportions:—

Water, HO; 9·.

Common Oil of Vitriol, specific gravity, 1·848; SO^3, HO; 49·.

Strongest Hydrochloric Acid, sp. gr. 1·21; $HCl, 6HO$; 90·5 (*i.e.*, 90 and 5-tenths).

Strongest Nitric Acid, sp. gr. 1·52; NO^5, $2HO$; 72·.

Sesquicarbonate of Ammonia (Sal-volatile); $2\ NH^3, 3CO^2, 2HO$; 118·.

Hydrochlorate of Ammonia (Sal-ammoniac); NH^3, HCl; 53·5.

Hydrate of Potash (fused Caustic Potash; KO, HO; 56·2.

Crystallized Carbonate of Potash; KO, CO^2, HO; 51·2.

Carbonate of Soda, (ordinary washing Soda); NaO, CO^2, $10HO$; 143·2.

Chloride of Sodium; $Na\ Cl$; 58·5.

Caustic Lime; CaO; 28·.
Calcined Magnesia; MgO; 20·2.
Ordinary Carbonate of Magnesia; MgO, CO^2, HO; 51.2.
Oxide of Zinc; ZnO; 4·6.
Commercial Sulphate of Zinc (White Vitriol); $ZnO, SO^3, 7HO$; 143·2.
Sesquioxide of Iron (Crocus, Colcothar); Fe^2O^3, 80·0.
Commercial Sulphate of Iron (Green Vitriol); $FeO, SO^3, 7HO$; 138·.
Protoxide of Copper (Black Oxide of Copper); CuO; 39·7.
Oxide of Silver; AgO; 116·1.
Commercial Sulphate of Copper (Blue Vitriol); $CuO, SO^3, 5HO$; 125·.
Chloride of Silver; $Ag\ Cl$; 143·6.
Nitrate of Silver; $AgO\ NO^5$; 170·1.
Oxide of Gold; AuO; 205·.
Terchloride of Gold; $Au\ Cl^3$; 303·5.
Bichloride of Platinum; $Pt\ Cl^2$; 169·7.
Cyanogen; Cy; 26·.
Cyanide of Potassium; KCy; 65·2.
Cyanide of Zinc; $Zn\ Cy$; 58·6.
Sesquicyanide of Copper; Cu^3, Cy^2; 148·.
Cyanide of Mercury; $Hg\ Cy$; 126·.
Cyanide of Silver; $Ag\ Cy$; 134·1.
Cyanide of Gold; $Au\ Cy$; 22·3.

57. *Definite Electro-Chemical Action.*—The chief mathematical condition is, that in every case of electro-deposition, all the actions, both of combination and decomposition, take place in certain mathematical proportions, that is, according to the relative atomic weights of the substances combining or being decomposed. For instance:—

1st. *With One Metal and One Liquid.*—If a piece of pure iron is immersed in a solution of sulphate of copper, it is dissolved, and copper is deposited; and for every 28 parts, or one atomic combining equivalents of iron dissolved, 31·7 parts, or one atom, of copper are deposited, and 49 parts (one equivalent) of hydrate of sulphuric acid (common oil of vitriol) are separated from the copper, and combine with the iron, forming therewith one equivalent of protosulphate of iron.

2nd. *With Two Metals and One Liquid.*—If a piece of zinc and a piece of silver in mutual contact are immersed in a solution of nitrate of silver, the zinc will dissolve and the silver receive a deposit; and for every 108·1 parts of silver deposited, 32·6 parts of zinc will be dissolved.

3rd. *With One Metal and Two Liquids.*—If one piece of copper is immersed in a solution of sulphate of copper, and another in dilute sulphuric acid, the two being connected together by a wire, and the liquids touching each other by a porous partition, copper will be dissolved in the dilute acid in the proportion of 31·7 parts for every 31·7 parts of copper deposited in the metallic solutions; and for every 49 parts, or one equivalent, of hydrate of sulphuric acid set free at the cathode by the deposition of the equivalent of copper, one equivalent of acid will combine with a like amount of copper at the anode.

4th. *With Two Metals and Two Liquids.*—If we immerse a piece of zinc in dilute sulphuric acid, and a piece of silver in a solution of double cyanide of silver and potassium, the two metals being connected by a wire, and the liquids touching each other by a porous partition, one equivalent, or 32·6 parts, of zinc will combine with one equivalent of the acid, and one equivalent, or 108·1 parts, of silver will be deposited, setting one equivalent, or 26 parts, of cyanogen free.

5th. *With a Separate Depositing Liquid.*—If the plates of a battery are connected by wires with two pieces of gold in a hot solution of double cyanide of gold and potassium, for every atomic equivalent, or 197 parts, of gold deposited and one equivalent of cyanogen set free, one equivalent of gold will combine with one equivalent of cyanogen, and dissolve; and not only this, but for each of these actions one equivalent of zinc will combine with one equivalent of acid, and one equivalent of hydrogen will be evolved in each of the battery cells supplying the current of electricity.

6th. *In a whole Series of Depositing Liquids.*—Such, for instance, as solutions of sulphate of copper with electrodes of copper,—arranged as in Figs. 15 and 16,—connected with a piece of zinc immersed in dilute sulphuric acid, and a piece of copper immersed in a solution of sulphate of copper, the two liquids touching each other by a porous diaphragm, the whole of the combinations, decompositions, and depositions of metal, throughout the series, will take place in the proportions of their atomic weights or chemical equivalents. These, and many other instances which might be adduced, prove that all the electro-chemical actions taking place in any given circuit, occur in certain definite proportions, and that this definite electro-chemical action is one very important condition of electro-deposition.

58. **Binary Theory of Electrolysis.**—The law of definite electro-chemical action was first established by Faraday, and in addition he has advanced what is termed the binary theory of electrolysis—that "only those compounds of the first order are *directly* decomposible by the electric current, which contain one atom of one of their elements for each atom of the other; for instance, compounds containing one atom of hydrogen or metal with one atom of oxygen, iodine, bromine, chlorine, fluorine, or cyanogen;" whilst "boracic acid ($B O^3$), sulphurous acid ($S O^2$), sulphuric acid ($S O^3$), iodide of sulphur, chloride of phosphorus ($P Cl^3$) and ($P Cl^5$), chloride of sulphur ($S^2 Cl$), chloride of carbon ($C^4 Cl^6$), bichloride of tin ($Sn Cl^2$), terchloride of arsenic ($As Cl^3$), quintochloride of antimony ($Sb Cl^5$)," are non-conductors of electricity, and incapable of electrolysis. Some substances, which are not of the simple binary character mentioned, are decomposed by current electricity, and yield their positive and negative elements in equivalent proportions at the respective electrodes; but, according to this theory, they are *indirectly* decomposed, *i.e.*, they are decomposed by the chemical action of some of the elements set free by the direct action of the current upon other substances present. For instance, "fused borax (biborate of soda $NaO, 2BO^3$) yields oxygen gas at the anode and boron at the cathode; now, since fused borax is not decomposible by the electric current, the separation of the boron must be attributed to indirect action; the current resolves the soda (NaO) into oxygen and sodium, and the latter separates boron from the boracic acid." (Faraday.) Again, an aqueous solution of ammonia (HO, NH^3) yields, by electrolysis, nitrogen gas at the anode and hydrogen at the cathode. In this case, according to the theory, it may be supposed that only the water (HO) is *directly* decomposed, and that its oxygen, set free at the anode, combines chemically with some of the hydrogen of the ammonia, again forming water, and thus indirectly its nitrogen is set free.

59. **Mathematical Idea of Electro-depositing Force.**—A consideration of the law of definite electro-chemical action, and the binary theory of electrolysis, leads us to view the electric current or depositing force in a mathematical aspect, as "an axis of forces equal in power, but opposite in direction," because, for every atom of an electro-positive substance attracted or transferred in one direction, an atom of an electro-negative character is attracted in the opposite direction. It also suggests to us the idea that an intimate connexion exists between those equivalents or mathematical relations of matter and the development of current electricity by chemical action, and its transference through liquids by electrolysis, because these phenomena only occur when the mathematical conditions are present.

60. **Sizes of Electrodes, Liquids, and Wires.**—The rapidity of deposition is influenced by the area of the electrodes, the length and area of the intervening liquid, and of the connecting wire; the larger the immersed surfaces of the metals, the shorter the length and the greater the transverse area of the liquid between them, and the shorter and thicker their connecting wires, the more rapid is the process of deposition. If the anode is very large and immersed in the lower part of the liquid, and the cathode very small and suspended near the surface, much more metal will be dissolved than is deposited, gas being generally evolved at the cathode in place of some of the metal deposited.

61. **Rapidity of Deposition.**—The character of the deposited metal is very much influenced by the rapidity of deposition: if it is deposited very rapidly, it will be in the state of a perfectly black, soft, non-coherent powder; if deposited more slowly, it will possess the ordinary characters of the particular metal; and if deposited very slowly, it will be crystalline, because the atoms are then allowed sufficient time to arrange themselves in the crystalline form.

62. **Logical Conditions.**—The logical conditions of deposition are—1st, that in all cases there is a *difference* either in the "*material substratum*," of metal, of liquid, or of both; or in the *forces* involved, both of chemical affinity and electricity, probably also of heat and of motion; and, 2nd, that in all cases of deposition there are certain chemical, electrical, thermic, dynamic, and mathematical conditions invariably present, and certain other conditions of each of those kinds invariably absent, both of which classes of conditions are necessary to the production of the phenomena; the whole of the necessarily present circumstances constituting its causes, and all the necessarily absent ones constituting its preventives; and if *all* the causes of deposition are present, and *all* its preventives absent, deposition will invariably occur; but if only one of its causes is absent, or one of its preventives present, deposition cannot take place.

63. **Ontological Condition.**—The last, the most necessary, most evident, and most simple condition of all deposition is—that metals, liquids, and forces are required in order to produce it.

THE PRACTICE OF ELECTRO-DEPOSITION.

64. **Objects of Practical Deposition.**—In the theoretical division we have brought forward a large number of instances, both of deposition and non-deposition; and from a consideration of them we have drawn conclusions both as to what substances and arrangements, and what conditions of those substances, really existed in cases of deposition; and, in similar cases of non-deposition, we have pointed out in what respect the conditions varied. Our object in pursuing this course was to impress the reader with a perfect knowledge of the theoretical principles on which deposition proceeds, that he may feel himself perfectly able to apply his knowledge to remove the difficulties certain to arise in his practice. Now, however, our object is different; it is to instruct the reader how he is to apply those principles in daily working, to give him practical rules, recipes, and directions for carrying out the various minute points in workshop manipulation; and to enable him to obtain the greatest degree of practical success.

65. **General Arrangement of Electro-Deposition.**—The practical part will be best arranged by beginning at the very commencement; and assuming the reader to be without materials or apparatus of any kind—that he has to provide a workshop,

prepare his solutions, batteries, scouring and cleaning apparatus; that he has to clean his articles for receiving deposits, and prepare his materials for moulds, before he can commence the process of deposition, gradually acquiring a knowledge, as he proceeds, of the kind of depositing process best fitted for his purpose; of the most suitable source of depositing power; the best solutions; the best recipes for making solutions; the construction of voltaic batteries and of magneto-electric machines; the rules for regulating the currents of electricity, and the character of the deposited metals; rules for depositing metals generally, as well as for cleaning and preparing metal articles to receive deposits; copying works of art by moulding; preparation of moulds for receiving deposits; making solutions for ordinary coppering, silvering, and gilding; and for the management of those solutions;—all these it will be our task to supply.

66. **First Considerations.**—The first step in practice is, to consider the probable magnitude of the operations to be carried on, and to provide rooms of suitable size. These should be upon the ground floor (except for electro-gilding), well lighted and ventilated, with conveniences for the erection of boilers and drying flues, for placing washing troughs, depositing vats and batteries, and for the escape of unwholesome vapours; there should also be ready access to a plentiful supply of clean water. The establishment should consist of at least three rooms, and an open yard with an outhouse; an upper or more private room for gilding, a ground-floor room for silvering, and another ground-floor room for the coarser work, such as coppering, brassing, and the preparation of the larger and coarser articles for receiving deposits. The outhouse is for the batteries, and the yard for washing the battery cells. If a magneto-electric machine is employed, an additional small, dry, and clean apartment will be required, which should be reserved for it alone.

67. **Boilers, Furnaces.**—For the purpose of general deposition, several large iron boilers, with furnaces beneath, either in the coppering-room or in close proximity to the silvering-room, are required; these are to contain solutions of caustic potash for cleaning articles. A low furnace should be erected between those rooms, having a long horizontal flue covered with plates of iron, for drying deposited or plated articles upon; the room for coppering should be furnished either with a low furnace or stove for heating the solutions used for coppering or brassing iron. Each room, whether for coppering, silvering, or gilding, should be provided with a tap of running water, and a leaden trough beneath, for washing the smaller articles; and the coppering-room should be furnished with one or two large wooden tubs or troughs, filled with water, for washing articles of larger size; both this room and the outhouse should contain a number of large stoneware pans and jars, oval and round, of different sizes and proportions, to contain the various "pickling" and "dipping" liquids, acids, or spent solutions. Several large iron trays, filled with sawdust, should also be provided and fitted to the furnace flue, for drying plated and deposited articles upon. Each of the rooms should be provided with a "scratch-brush lathe," for scouring the various articles. The gilding-room should have several small stoves for heating gilding solutions, or, in lieu thereof, several iron tripods, with large gas burners beneath. The silvering and coppering-rooms should each be provided with one or two pairs of large and well-insulated copper wires, proceeding from the depositing vats to the batteries outside. The gilding-room will not require these, small batteries only being used in it, which are kept in the same room.

68. **Source of Electricity.**—A point for early consideration will be whether a

magneto-electric machine or voltaic batteries are to be used as the source of depositing power. The choice of the former will depend very much upon the degree of confidence the operator possesses in each source of electricity, upon its expense, and whether or not motive power to drive it is readily and constantly available at a moderate cost. Voltaic batteries are readily obtained and worked in almost any situation. We will suppose, for the purpose of explanation, that the operator has resolved to use both a magneto-electric machine and voltaic batteries; and, therefore, we will explain the construction of each.

69. **Construction of Magneto-Electric Machine.**—The simplest form of apparatus for generating current electricity by the joint influence of magnetism and motion has been already described (15), but the apparatus required for practical purposes is far more elaborate and costly in its construction. A (Fig. 22) is a strong framework of wood; B, B, B, B are four bundles of powerful horse-shoe magnets, firmly fixed to the wooden frame; C is an axle driven very rapidly by steam-power; the axle carries two brass circles, upon which, at right angles, are firmly fixed four round bars of pure soft iron, equal in length to the distance asunder of the poles of each magnet, upon each of which is coiled a long piece of thick copper wire, the wire being covered with cotton to insulate its coils from each other; the ends of these wires are connected with four semicircular pieces, formed of a piece of brass tube, fixed upon the axle C, but insulated from it and from each other (Fig. 23) by a tube of hard wood or gutta-percha; by rotation of the iron armatures past the poles of the magnets, currents of electricity are generated in the wires in one direction as they are approaching the magnets, and in an opposite direction as they recede from them; and to collect those currents and convey them to the depositing vat, also to throw them all into one uniform direction, two brass springs, D E press against the semicircles of brass during their revolution, and are so arranged at their points of mutual contact that, just at the moment that the currents are changed in direction by the armatures passing the magnets, the revolution of the axle causes the points of contact of the springs to pass from one pair of the semicircles to the other; and thus, by reversing the connection at the moment the direction of the current is changed, an uniform direction of currents is obtained in the wires beyond.

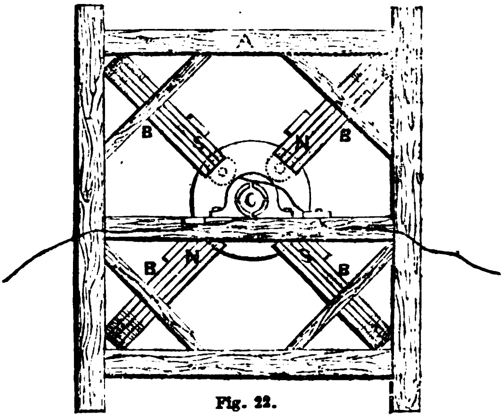

Fig. 22.

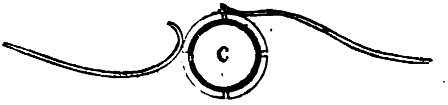

Fig. 23.

To explain the action of this machine more fully, we will suppose NS, NS, Fig. 24), to represent those poles of the compound horse-shoe magnets which are towards the observer in the elevation (Fig. 22), A is the axle, and B, C, D, and E are the ends of the four horizontal round iron bars or armatures, moving in the direction of the large arrows. When a bar of soft iron, having a coil of insulated wire wound upon it, is moving *towards* a pole of a magnet, a current of electricity is developed in the wire in *one* direction by the piece of iron within it *gaining* magnetism; and when the bar is moving *from* the pole of the magnet, a current is produced in an *opposite* direction by the iron bar *losing* its magnetism; and these currents are both reversed in direction, if the pole of the magnet is reversed; so that the current developed in a wire, coiled upon an iron bar, by moving that bar *towards* the *south* pole of a magnet, is the same in direction as that produced by moving it *from* the *north* pole. We will now suppose that the current produced in the coil of wire upon bar B, moving from S to N, is in the direction of the small arrow surrounding that bar, viz., *left*-handed motion; if so, the current of the wire of bar D will also be *left*-handed in direction, because it also is moving from a south to a north pole; whilst the currents in the wires of bars C and E will be *right*-handed, because both those bars and coils are moving from north to south poles.

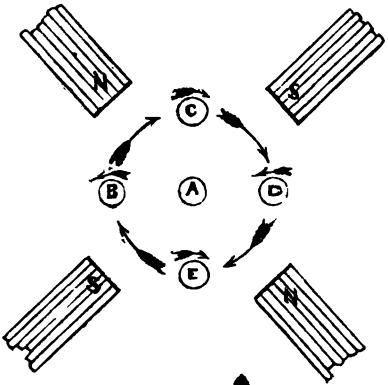

Fig. 24.

From these remarks, by careful attention, it may be perceived:—1st, that the currents of electricity, in all the coils, are reversed in direction every time the bars pass the centres of the poles of the magnets, *i.e.*, four times in every revolution; 2nd, that to obtain a current of one uniform direction from all the four coils (by conducting the whole four into one stream), during *only one quarter* of a revolution, *i.e.*, from one pole to the next one, it is necessary to connect the ends of the wires of the coils of B and D in an opposite manner with the semi-cylinders of the commutator or break-piece (see Figure), to those of the coils of C and E; and, 3rd, that as the currents in all the coils are reversed in direction every time the bars pass the centre of the poles of the magnets, the two springs which press upon the semi-cylinders, must, by some means or other, be reversed in their order of connection with all the wires every time, and at the same moment that the bars pass the centres of the poles, in order to throw the whole of the currents during a complete revolution into one uniform direction in the springs and in the wires which proceed to the depositing vessel.

To enable us to understand how the opposite currents of the different coils are thrown into one uniform direction during one quarter of a revolution, and how the whole of the currents are alternately conducted into one uniform stream during rapid revolution, we will suppose A (Fig. 25) to be the axle, and 1, 2, 3, and 4, the semi-cylinders insulated from the axle by a tube of gutta-percha. In the first place 1 and 2 are connected together by a short piece of thick copper or brass wire, or a strip of sheet copper behind (not shown in Figure), and 3 and 4 are connected together by another and similar piece of metal; next, the ends of the wires A, A, A, A are gathered into one bundle, and connected by soldering with the wire or strip of metal of the semi-cylinders

1 and 2, and the ends B, B, B, B are connected in like manner with the semi-cylinders 3 and 4; and by this arrangement, on careful attention, it will be perceived that the whole of the currents are thrown into one direction during *one quarter* of a revolution. In the sketch, the bars are just approaching the centres of the poles, and the semi-cylinder 1 is just about breaking contact with spring C′, and semi-cylinder 4 is about making contact with it; semi-cylinder 3 is about passing from spring D′, and semicircle 1 is about making contact with it. In this position of the bars, it will be perceived that all the A ends of the wires, the semi-cylinders 1 and 2, and the spring C′, are positive, as indicated by the arrows; whilst the B ends, the semi-cylinders 3 and 4, and the spring D′ are negative; but immediately the bars pass the centres of the poles, the currents are all reversed in direction—all the B ends of the wires, and the semi-cylinders 3 and 4 become positive, and the A ends, and the semi-cylinders 1 and 2 negative; but as the rotation of the axle shifts the points of contact of semi-cylinder 1 to spring D′, and of semi-cylinder 4 to spring C′, at the same moment, the spring C′ still remains positive, and D′ negative, as before. The connections of the springs with the semi-cylinders in the other two quarters of the revolution, alternate in a similar manner; and these alternations take place regularly, and synchronously with the reversals of the currents, no matter how rapidly the axle revolves; and, notwithstanding the incessant and indefinitely rapid changes of the currents, one uniform stream of electricity is obtained. In the practical machine, the bars of iron rotate as closely as possible to the ends of the magnets without absolutely touching them, in order to obtain the greatest amount of power; and the power is regulated by placing the soft iron keepers which are upon the magnets (Fig. 23) nearer or further from the poles; the keepers are secured to the magnet, that they may not fall off by the vibration of the machine. Two wires proceeding from the springs are connected, one with the dissolving plates and the other with the receiving articles in the vat. The machine may contain either eight revolving armatures or eight magnets, according to the amount of work to be effected.

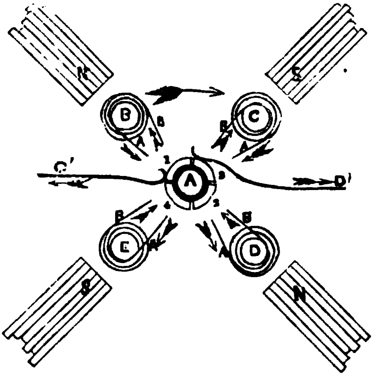

Fig. 25.

70. **Voltaic Batteries.**—Each of the arrangements of metals and liquids which have been described under the head of "Facts," and which develop a current of electricity, constitutes an elementary voltaic battery—a battery in all its essential parts in principle, but not in outward form. All voltaic batteries consist of one or other of those theoretical arrangements modified and adapted for practical use, and are composed either of two metals and one liquid, or two metals and two liquids; because these two arrangements develop the greatest amount of electricity, and are most convenient in use. In the theoretical form any kind of metal, of any size or shape, with almost any conducting liquid, and with any kind, shape, or size of containing vessel, will develop a current and produce deposition; but a true voltaic battery—the *practical* instrument—consists of particular metals and liquids (those which evolve the greatest power), of

particular sizes, shapes, and proportions, and at certain distances apart, with suitable screws attached for connections, and with containing vessels made of particular materials, and of special forms and sizes.

71. The kinds of batteries most in use for electro-deposition are—

1st. The old zinc and copper battery (Fig. 26), each pair of which consists of a cross piece of wood at the top, with a groove in it for passing down the zinc plate, and two copper plates, one on each side of the zinc, which are prevented from touching it by a slight frame of wood attached to the cross piece; the zinc plate is moveable vertically, and has a strong cramp screw attached to support it at any given height, and with which to form connection; the copper plates are connected together by a strip of sheet copper, they have also a screw for forming connections; they do not touch the bottom of the vessel by several inches, being supported by the cross head upon the upper edges of the vessel.

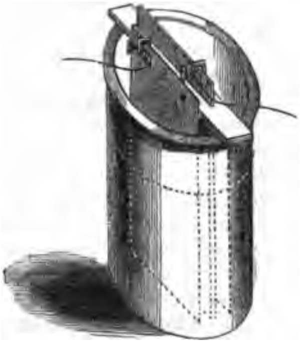
Fig. 26.

2nd. Smee's battery of zinc and platinized silver, is similar in arrangement to the one described, except that the sheets of platinized silver, being exceedingly thin, are stuck upon the board by shellac varnish, the board being previously saturated with that substance to prevent the battery liquid from acting upon it.

3rd. Daniell's battery (Fig. 27), consisting of a piece of zinc, either in the form of a round bolt or thin cylinder; this is immersed in dilute sulphuric acid, and a cylinder of sheet copper immersed in a solution of sulphate of copper, the two liquids being separated by a porous diaphragm; the zinc is generally contained with the dilute acid in a porous vessel, which is immersed in an outer vessel combining the cylinder of sheet copper and the sulphate solution, or the outer vessel itself is formed of copper, and constitutes the negative metal. In each case a small perforated shelf is placed near the upper end of the battery, containing crystals of sulphate of copper for supplying the outer liquid.

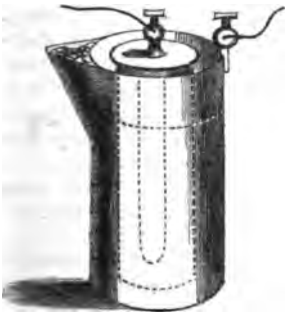
Fig. 27.

4th. For purposes where a current of considerable intensity is required, a battery of cast-iron and zinc is provided.

72. **Battery Cells.**—The form of cells for these batteries is generally either round or square; for *small* batteries, either of the old zinc and copper kind, or of Mr. Smee's arrangement, square ones are generally used, but for small Daniell's batteries, or for large batteries of either of these kinds, round vessels are almost invariably adopted. They are made of stoneware, glass, or gutta-percha; the first of these is universally used for large batteries of all kinds; glass is too expensive for large vessels, but it possesses the great advantage of enabling the operator to watch the action of the batteries, and is now being moulded into large vessels for the use of some of the electro-plate manu-

facturers; gutta-percha has been also used, but possesses rather less advantage upon the whole, than the other materials, being opaque and expensive, while the zinc salt of the battery liquid passes rather rapidly over its edges by capillary action.

73. **Porous Cells.**—When Daniell's or any other battery with two liquids is used, porous vessels are required also to allow the two liquids to touch each other without mixing; they are of three kinds—unglazed earthenware, wood, and bladder; the first of these is the only kind in use by manufacturers; they should always be kept in clean water when not in use, to remove the salts of the battery liquids from them, to prevent their cracking, and to preserve them always fit for immediate use.

74. **Zinc for Batteries.**—The best kind of zinc for batteries, and the kind chiefly in use by electro-platers, is the German or Liege zinc, known as "Mosselman's," from the name of a firm who manufacture it. The thickness of the plate should vary with the size of the battery; the smallest should not be less than one-eighth of an inch thick, on account of its brittleness when amalgamated; large ones are generally about one quarter or three-eighths of an inch in thickness. Zinc bolts for Daniell's batteries are generally made by melting together a number of old worn-out pieces of battery plates, and casting it in a suitable mould. The wholesale price of unrolled (cake) zinc is about twenty-five shillings per hundredweight.

75. **Amalgamation of Zinc.**—Zinc plates or bolts are best amalgamated by immersing them about a quarter of an hour in a mixture of about one part of sulphuric acid and ten or twenty parts of water; then pouring mercury upon them, and rubbing it all over them with a hare's foot or piece of old cloth, using a small hard brush for the refractory places; they are then washed in water, and drained for half an hour, and brushed to recover the superfluous mercury.

76. **Copper and Platinized Silver for Batteries.**—Ordinary sheet copper answers very well for this purpose, and platinized silver may be obtained of most philosophical instrument makers, or it may be easily prepared by any one by the following means:—immerse a piece of zinc in dilute sulphuric acid contained in a porous cell, place the cell in an outer vessel, and fill the outer space with water, to which a few drops of sulphuric acid have been added; add to this a sufficient quantity of a solution of bichloride of platinum to render it of a brown colour; immerse the piece of silver to be platinized in the outer liquid, and connect it by a wire with the piece of zinc; gas will soon be evolved from the surface of the silver, and the silver will gradually become black with a deposit of platinum; it may then be removed, dipped several times in water, and afterwards dried, care being taken not to rub off the platinum. The porous cell requires to be immersed a short time beforehand. The solution of bichloride of platinum may be easily and cheaply formed by adding scraps of platinum foil to a hot mixture of one measure of nitric acid and two and a half measures of hydrochloric acid, as long as gas is evolved from them; the liquid will then be of a deep red colour. Silver alone is not nearly so effective for the negative metal of voltaic batteries as platinized silver, because the hydrogen gas evolved adheres very strongly to it, and greatly reduces the amount of its surface in contact with the liquid, whereas the platinum being a very negative metal, and being deposited in the state of a fine powder, causes the hydrogen to be thrown off very rapidly from its surface, and thus increases the action.

Copper is still less effective than silver, because the battery liquid acts chemically upon it and forms a salt of copper, which dissolves in the liquid and re-acts upon the zinc plates, causing them to waste rapidly; for this reason they cannot, like silver, be safely left in the liquid any great length of time when the battery is not at work. In addition to this, when they are taken out and exposed to the air they soon become covered with a film of oxide, which considerably weakens the electric current on their re-immersion.

77. **Depositing Vessels, Vats, &c.**—The depositing vessels are made of various materials. For small operations nothing is so suitable as glass vessels or a stoneware pan; but for ordinary manufacturing purposes, vats containing from twenty to several thousands gallons are used; they are generally made of wood lined with sheet lead; but very large ones, for containing sulphate of copper solution, such as are used for depositing life-sized figures in copper, have in some instances been built of bricks, coated with cement, and lined with gutta-percha. Vats used to contain cyanide solutions should not be lined with this substance, because the cyanide of potassium acts upon it. The vats used for ordinary silver-plating are about twenty-four or thirty inches deep, from two to three feet wide, and from three to twenty feet long; their dimensions vary greatly in different manufactories, and depend upon the number and size of the articles to be plated in them. Some electro-depositors use vats formed of sheets of wrought iron riveted together; but there is always a slight salt or sediment found on their sides, which settles at the bottom of the liquid.

78. **Arrangement of Dissolving Plates in Vat.**—In the vats used for silvering general articles, such as spoons, knives, forks, teapots, plates, &c., the dissolving plates are sometimes fixed all round the sides of the vessel just beneath the surface of the liquid; in addition to this, vertical wooden frames are fixed at intervals of about two feet, across the vat, (Fig. 28), with dissolving plates upon them, and all the dissolving plates are connected together. The articles to be plated are suspended by small copper wires, from brass or copper tubes resting across the vessel upon two other and longer tubes passing all along the upper edges of the vat, and connected by a large copper wire with the negative pole of the battery, whilst the dissolving plates are connected by another large copper wire with the positive pole; by this arrangement each row of the articles has dissolving plates all round it, which greatly facilitate the rapidity of deposition. The wooden cross frames are moveable, so that when large articles are to be plated, one or more of them may be removed to make room.

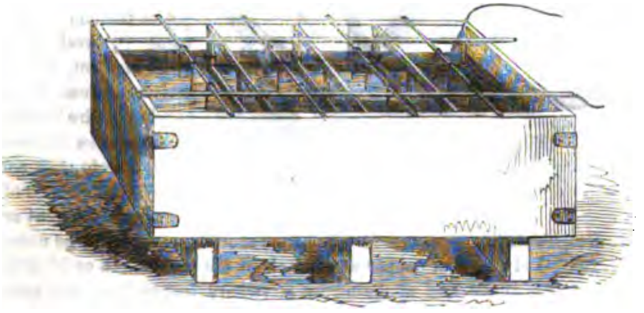

Fig. 28.

79. The large vessels used for depositing solutions which require to be worked, *hot* such as the cyanide coppering or brassing liquids, are formed either of cast iron, wrought

iron, or iron coated with enamel; and the smaller vessels, such as are used for gilding, are oftentimes of stoneware or glass; enamelled iron pans are also used for this purpose.

80. "**Scratch-brush Lathe.**"—The deposition will require several "scratch-brush" lathes, one in each depositing room, for scouring and preparing the surfaces of metal articles to receive a deposit. This instrument (Fig. 29) consists simply of an ordinary lathe A, with a wooden chuck B, to the sides of which are firmly secured four horizontal bundles of fine brass wire; above it is a vessel C, containing stale beer, which is allowed to drop constantly, by the pipe and tap D, upon the revolving brushes whilst working; the sides E E are to prevent splashing, and the tray F and pipe G are to collect and convey the waste liquid. The workman stands opposite the end of the machine in using it, working the treadle with his foot, and pressing the article against the ends of the revolving wire brushes, exposing in succession different parts of the article to their action. Wire of different degrees of fineness is used with different articles.

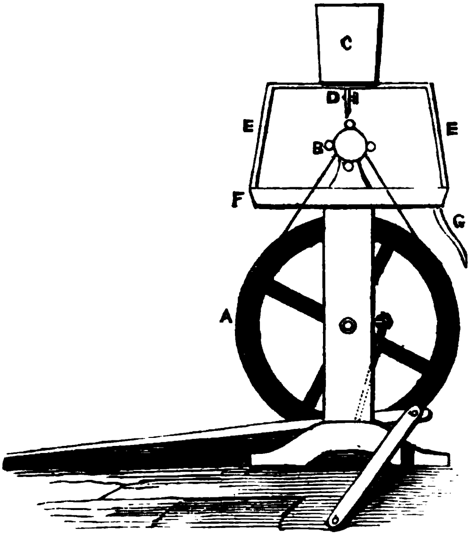

Fig. 29.

81. **Connecting Wires.**—The depositor should provide a large number (several pounds weight) of pieces of copper wire, of about the size No. 18 or 20 of the Birmingham brass wire guage, and about fifteen or twenty inches long, for suspending the smaller and more numerous articles to be coated in the depositing solutions; a few other pieces of a larger and stronger kind should be provided for the heavier articles. Copper is the most suitable metal for connecting-wires, and the most generally used, because it is one of the best conductors of electricity, being also flexible and not expensive; next to it we should select brass; silver is the best conductor, but is too expensive.

82. **Dipping Liquids, Pickling Liquids, &c.**—The depositor will next prepare his various liquids for cleansing articles for plating. For cleaning iron articles he will require large stoneware pans and jars, containing a mixture of one part of sulphuric acid, and twenty parts of water, or weaker, according to the kind and condition of the metal; smooth wrought iron requires a weaker liquid than rough cast iron. For cleaning either copper, brass, or german silver, he will require several stoneware pans, one containing strong nitric acid, another filled with "dipping" liquid (a mixture of 64 parts of water, 64 parts sulphuic acid, 32 parts nitric acid, and 1 part of hydrochloric acid), and a third containing "spent" liquid, *i.e.*, either nitric acid or dipping

liquid the power of which has been partly exhausted. In addition to these liquids, he will require some glass-cutters' fine sand; with several small hand brushes and pieces of old cloth, for brushing and rubbing the sand upon the more rusty and refractory parts of the metals to be cleaned; also a file and scraper to further assist in cleaning them. Hydrofluoric acid, contained in a small leaden or gutta-percha bottle, should be at hand, to apply to the "glazed" patches occasionally met with upon cast iron.

83. **Battery Liquids.**—The only kind of acid used by electro-platers to excite their batteries is sulphuric acid; it is obtained in large quantities at about one penny or three-halfpence per pound. For the negative solution of Daniell's batteries, a stock of sulphate of copper should be provided; its price varies from fourpence to fivepence per pound in large quantities.

84. **Liquids for Causing Adhesive Deposits.**—Solutions of nitrate, or of cyanide of mercury, will be required for preparing the surfaces of copper, brass, and german silver, for receiving adhesive deposits of silver. The nitrate solution is prepared by adding one ounce of mercury to sufficient nitric acid, diluted with three times its bulk of water to dissolve it; no more mercury must be added than the liquid will dissolve; when thoroughly dissolved, dilute it with about one gallon of water. To prepare the cyanide solution, dissolve one ounce of mercury as stated, dilute it with water, and add a solution of cyanide of potassium to it, just as long as a precipitate is produced; filter it, add a small quantity of water to the precipitate in the filter, and, when thoroughly drained, take it out and add to it a strong solution of cyanide of potassium until it is all dissolved, then add a little more cyanide solution, and finally dilute it with water until the whole measures one gallon. The solution when prepared is kept in a large stoneware pan, a pan of dipping liquid and another of water being near it, and each placed near the scratch-brush lathe and depositing vats in the silvering-room.

85. **Materials for Moulding.**—The electro-depositor who includes in his business not only the ordinary electro-plating, but also the manufacture of works of art by deposition, requires a number of substances for moulding, and preparing the surface of the moulds to receive a deposit. For moulding ordinary metal objects, he often uses wax in a composition consisting of equal parts of white wax, spermaceti, and gutta-percha; but one of the best substances we have used for this purpose has been a composition of our own, consisting of two parts of gutta-percha, and one part of Jeffery's marine glue; the glue is cut up into small pieces and melted at a gentle heat in an iron ladle, the gutta-percha, also cut very small, is then added, and the mixture constantly and vigorously stirred at a gentle heat until the two are thoroughly incorporated. In this state it is poured over the object to be copied. This substance possesses several important advantages over gutta-percha alone as a moulding material; it is softer when heated, and takes a sharper impression; it contracts more in cooling, and is therefore more easily removed from the original; and in taking the blacklead it is very superior to gutta-percha. With ordinary care many copies may be taken by deposition off one of these moulds; we have taken upwards of ten from one of them.

86. **Elastic Moulding Composition.**—When the objects to be copied are much under-cut, or when we wish to take a mould of a bust all in one piece, elastic moulding composition is required. The best substance of this kind, and almost the only one used, is composed of four parts of best Russian glue and one part of treacle; the glue is broken into small pieces and soaked for one or two hours, or until it is quite soft, in sufficient *cold* water to cover it; when it is soft the superfluous water is

thrown away, and the glue, together with the treacle, is heated in a common glue-pot, like ordinary glue, to nearly a boiling heat, and stirred until the two substances are thoroughly mixed; the use of the treacle is to prevent the mould drying and shrinking too rapidly.

87. **Blacklead, Phosphorus Liquid, &c.**—For rendering the surfaces of non-conducting substances, such as gutta-percha, wax, marine glue, &c., conductible, the application of several substances will suffice:—

1st. The common powder blacklead for ordinary non-elastic moulds; there is the greatest difference, however, between different specimens of blacklead in their value for this purpose, some causing the deposit to spread over the moulds very quickly, whilst others scarcely cause it to spread at all; the best we have found, and it has been very good, is "Dix's," sold in twopenny packets, one or two of which will serve the operator a long time for this purpose.

2nd. For the moulds made of elastic composition (86) he will require the following liquids, patented by Mr. Alexander Parkes:—A, the phosphorus solution—to make nearly three ounces of which, melt 64 grains of bees-wax or tallow; then dissolve eight grains of india-rubber cut up very small, in 160 grains of bisulphide of carbon, and when it is dissolved add to it very carefully (as it is highly inflammable) the melted wax, and shake the mixture thoroughly; then dissolve 64 grains of phosphorus in 960 grains (about 2½ ounces) of bisulphide of carbon, and add to it 80 grains of spirit of turpentine, and 64 grains of asphalte in fine powder; when dissolved, add this solution to the previous one of india-rubber and wax, and thoroughly mix them by shaking. B, the silver solution—to make twenty ounces (one pint) of this liquid, dissolve about 18 or 19 grains of pure silver in about 20 or 25 grains of the strongest nitric acid, and then dilute it to the required volume with *distilled* water. And C, the gold solution—to make 20 ounces of which, dissolve about 5 or 6 grains of pure gold in about 20 or 25 grains of a hot mixture of one measure of nitric acid, and about two or three measures of hydrochloric acid, and, when dissolved, dilute the solution with 20 ounces of *distilled* water.

The same patentee includes in his patent a phosphorus moulding composition, by the use of which the immersion in the phosphorus solution is dispensed with, the moulds themselves containing the required amount of phosphorus; to make about one pound of this composition, melt together half a pound each of wax and deers' fat, then dissolve about 19 or 20 grains of phosphorus in about 300 grains of bisulphide of carbon; keep the wax mixture barely melted, and add the phosphorus solution slowly to it, and with brisk stirring of the fat, pouring it in at the bottom of the melted mixture by a vessel with a long spout, to prevent its inflaming. It is highly dangerous to leave spilled portions of the phosphorus solution or composition about in contact with wood, paper, rags, &c., as after a lapse of some time (even hours) they will often burst into flame.

88. **Selection of Depositing Processes.**—For very small articles of which there are a great number, such as buttons, hooks and eyes, pins, &c.; and which require only a very thin deposit, the simple immersion or wash process will answer very well, being both easy of execution and cheap. For the multiplication of numerous small articles in copper, such as medallions, &c., the single cell process is very advantageous; it is quicker than the battery process, and considering the time occupied, and the other elements of expense, it is to be preferred to that method. But for all ordinary deposits, plating, &c., the battery process is by far the best, because coatings

of any thickness, in all ordinary metals, may be obtained by it, and the solutions do not, as in the other processes, require renewal.

89. **Methods of Making Depositing Solutions.**—The operator will next consider about making depositing liquids. They may be made by two methods, the one called the chemical and the other the battery process. The chemical process consists of the various ingredients by the usual chemical means, and adding them together in suitable proportions to form the complete liquid; for instance—1st, the ordinary sulphate of copper solution is prepared by dissolving a certain proportion of commercial sulphate of copper in water, and adding to it a certain proportion of sulphuric acid to form *free* acid; and, 2nd, to form the ordinary cyanide of silver and potassium plating liquid, silver is dissolved in dilute nitric acid; the solution of nitrate of silver formed is precipitated by addition of a solution of cyanide of potassium; the white precipitate of cyanide of silver is washed, and then added, as much of it as will dissolve, to a solution of cyanide of potassium; after that an additional portion of cyanide of potassium is added to form *free* cyanide. The battery process consists in taking some water and dissolving in it a certain proportion of acid or salt, as the case may be, then placing a large anode of the given metal at the lower part of the liquid and a small bright cathode at the upper part, and, if necessary, applying heat, and connecting them with a suitable battery until the required quantity of metal is dissolved, which is indicated by the cathode receiving a good deposit; in making gold solutions the cathode is generally placed in a small porous cell filled with the same liquid, and immersed nearly to its edge in the outer liquid, and by transferring the cathode occasionally to the gold solution, and absorbing; if it receives a good deposit, we may know that sufficient metal is dissolved; the liquid of the cell may then be added to the outer solution. If it is wished to make sulphate of copper solution by this method (which we should not advise, however, the salt being so cheap), take the same quantity of water as we prescribed for the chemical method, and add to it as much acid as was contained in the salt of copper, with the free acid as before, and then pass a current from a battery of one or two pairs by a large anode and small cathode, until sufficient metal was dissolved; or if it is desired to make some cyanide of silver and potassium solution by this method, which is sometimes done, take the same proportions of water, cyanide of potassium, and free cyanide as in the chemical process, and pass the current by a large silver anode, until the same proportion of silver is dissolved as required in the chemical method.

90. **Selection of Depositing Liquids.**—The following rules should be observed in selecting a suitable depositing liquid for the battery process.

1st. It should act strongly upon the anode, and hold abundance of metal in solution.

2nd. It should possess good electrical conducting power.

3rd. It should yield its metal freely, and in a reguline state.

4th. It should not act chemically to any great extent upon the base metals, because it is that we generally wish to coat, and chemical action upon it would endanger the adhesion of the deposited metal.

5th. It should not decompose by contact with the atmosphere, nor should light influence it in such a way as to injure it for depositing purposes.

6th. It is better if it does not evolve gas at the surface of the receiving article whilst depositing, because that generally indicates a waste of battery power attended by oxidation of the liquid.

91. **Testing a Depositing Liquid.**—To test a depositing liquid, pass a current of electricity through it, from about two pairs of Smee's batteries, with a suitable clean anode of proper size, and a clean piece of iron, brass, or copper, of about the same size, to receive a deposit, observing how much gas is evolved in the battery; if the deposit appears quickly, and is of a bright and proper colour; and if it adheres to the metal; if the cathode evolves gas from its surface, and the anode dissolves freely, cleanly, and without escape of gas, work it at intervals, keeping it exposed to light and air; observe if it continues to work well, or whether, on the contrary, it shows a decrease of conductibility, deposits a sediment, or if the anode becomes covered with an insoluble crust (this last may arise either from deficiency of free acid, or from impurities in the metal). If but little gas is evolved in the battery, it is a bad conductor, and will neither dissolve nor deposit the metal freely at that temperature, or it is deficient in *free* acid or *free* salt. If the deposited metal is of a bad colour, either the battery is too strong, the receiving article too small, or the liquid is incapable of yielding good metal. If the immersed metal or article is coated by simple immersion without the aid of the battery, it shows that, to adapt the liquid to articles made of that particular metal or alloy, they must receive some previous preparation, in order to make the deposit adhere. If it deposits a sediment, or altersein conductibility by exposure to the air and light, the greater probability is that those influences alter either its chemical composition, or the arrangement of its particles. If it evolves gas at the receiving surface during deposition, it shows either that there is too much battery power, too little metal in solution, too much *free* acid, or that it is a wasteful liquid, in which one part only of the current is employed in depositing metal, whilst another part of it is employed in depositing gas and oxidating the liquid.

92. **Testing Solutions for Depositing Alloys.**—With solutions in which alloys are to be deposited the most important condition is, that neither of the metals to be deposited are electro-positive to each other in that liquid. This is best tested by taking a wire of each metal, connecting them with a galvanometer, and simultaneously immersing their free ends in the liquid; if either is electre-positive, the needles of the instrument will be deflected, and the direction of the deflection will indicate which is positive, while the amount of deflection will indicate the amount of their electric difference in that liquid. It may also be tested by immersing a wire of each metal (not in mutual contact) in the liquid; if either becomes coated with metal in an hour, that one is positive; but if neither becomes coated in six hours, there is no perceptible electric difference between them.

93. The following experiments bear upon this part of the subject, and show that if a liquid contains two metals in solution, and a wire or other piece of each of those metals is immersed in the liquid, and one becomes covered with a deposit of metal, while the other does not, the one so covered is electro-positive to the other in that liquid.

1st Experiment. With an alloy solution consisting of equal measures of a strong solution of protochloride of tin, and terchloride of antimony, with an anode either of tin or antimony (the latter is the most proper, because it does not coat itself by simple immersion in the liquid), a copper cathode, and one pair of small Smee's battery, only antimony was deposited; tin coated itself with antimony in this solution by simple immersion, and was found by the galvanometer to be strongly positive to that metal.

2nd Experiment. With a liquid composed of equal measures of a solution of protochloride of tin and chloride of bismuth, and either a bismuth or tin anode (the former is the best), a brass cathode, and one pair of small Smee's batteries, only bismuth was deposited; tin was positive to bismuth in this liquid by the galvanometer, and coated itself quickly with that metal by simple immersion.

3rd Experiment. With a mixture of equal measures of terchloride of antimony, and chloride of bismuth, antimony anode, copper cathode, and a feeble Smee's battery, only antimony was deposited; bismuth coated itself slowly with antimony in it by the simple immersion, and was, by the galvanometer, moderately positive to the latter metal in it.

4th Experiment. With 100 grains each of protochloride of tin and chloride of zinc dissolved together in an ounce of distilled water, tin anode, copper cathode, and one pair of small Smee's batteries, only tin was deposited; zinc was positive to tin in this liquid by the galvanometer, and deposited tin upon itself by simple immersion.

5th Experiment. With equal measures of strong solutions of nitrate of zinc, and ternitrate of bismuth, and a little nitric acid, bismuth anode, copper cathode, and a feeble one pair battery, only bismuth was deposited; zinc was strongly positive to bismuth in this liquid by the galvanometer, and coated itself quickly with that metal by simple immersion.

6th Experiment. With a solution of the mixed sulphates of zinc and copper, copper anode and cathode, and a single small battery, copper alone was deposited; zinc was strongly positive to copper in this liquid by the galvanometer, and coated itself immediately with copper in it by simple immersion.

94. Further, if we take some distilled water, and caustic potash is dissolved in it, passing a moderately strong current through it by platinum electrodes, hydrogen gas will alone be set free at the cathode; in this case also hydrogen—the least positive of the two positive elements of the liquid—potassium and hydrogen—is set free or deposited. If we now add a little sulphuric acid to the liquid to convert it into a solution of sulphate of potash, add some sulphate of zinc besides, and pass a weak current through; we shall obtain a deposit of zinc on the cathode, but no hydrogen or potassium; in this case we cannot determine by the galvanometer which is the most positive in this liquid, hydrogen or zinc, because the former is a gas; but it is probable that hydrogen is the most positive, because zinc does not evolve it by simple immersion in this liquid. If we further add to the liquid a small quantity of sulphate of copper, and treat it as before, neither potassium, hydrogen, nor zinc will be deposited, but only copper; and we find by the galvanometer that copper is less positive than zinc in such a liquid, and that zinc coats itself with copper in it by simple immersion; in this case also the least positive of the positive elements of the liquid is alone deposited. From these and many other experiments, which we have tried with similar results, we deduce the following rule:—If a liquid contains several metals or other electro-positive substances dissolved, and a *weak* electric current is passed through it, only that substance which is the least electro-positive, and which has the weakest affinity for the acid or negative elements of the liquid, will be separated from its acid and be deposited.

95. With regard to the influence exercised by the proportions of the ingredients of the liquid, and the strength of the current, we may observe, that, if a liquid contains several metals dissolved in equal quantities, and only one is being deposited by the passage of a weak current, a considerable increase in the strength of the current will cause a portion of the next more positive metal to be deposited along with the less positive one; but this alloy deposit will not be very coherent, because the power required to deposit the second metal in the reguline state will be so great as to deposit the first as a soft powder. This holds most true when the difference of electric power required is the

greatest; for instance—1st, if small and equal quantities of sulphate of zinc and sulphate of copper are dissolved together in a large quantity of water, and a feeble current passed through the solution, only reguline copper will be deposited; but if the battery power be considerably increased, either by a greater number or larger surface of the battery plates, the deposit of copper will cease to be reguline, and zinc will be deposited with it. If the power be still further increased, hydrogen gas will also be evolved at the surface of the deposited metals. 2nd, If we dissolve a small quantity of sulphate of copper, and a large quantity of sulphate of zinc, in a large quantity of water, and pass a strong current through the solution, copper, zinc, and hydrogen will be set free at the cathode. 3rd, If we slightly moisten a lump of caustic potash with pure water, and pass a weak electric current through it by platinum electrodes, hydrogen alone will be set free at the cathode, but if a very powerful current is employed, potassium also will be deposited. In each of these cases we find, that when the current is weak, the least positive of the positive substances is alone deposited; but if the power is sufficiently increased, and there is only a small proportion of the less positive substance present, the more positive substances, even though they are much more positive, will also be deposited. Thus the weaker affinities are overcome first, and to the greatest extent; the current of electricity exercising its influence first, and in the greatest porportions, upon the salt of the least positive metals.

96. **Depositing Liquids**.—For the benefit of the practical depositor, to whom a general knowledge of all solutions from which ordinary metals may be deposited, with their respective advantages and disadvantages, is of considerable importance, we will give a description of those solutions in regular order, making such remarks in our progress as will be likely to assist him in the selection of those most suitable for his particular purposes.

97. *Antimony Solutions.*—The most common salts of antimony are the sulphide, terchloride, and potassio-tartrate. The hydrochlorate of terchloride of antimony, *i.e.*, the ordinary chloride or butter of antimony, as prepared for pharmaceutical purposes, is formed by chemical means thus:—take one pound of black sulphide of antimony, add to it four pints of hydrochloric acid, gently heat the mixture with constant stirring, until the gas evolved decreases, then boil it slowly down to two pints, keeping it partly covered all the time; cool it, filter it through calico, and keep it in a stoppered bottle. It is now a yellowish red liquid, of specific gravity 1·47, but becomes nearly colourless by depositing antimony from it by the battery process; the price of the commercial article is about ninepence per pound.

A similar solution may be made by the battery method; this consists in passing a current from several pairs of batteries through strong hydrochloric acid by a large anode of antimony, until a good deposit is obtained; this solution is nearly colourless. The chloride of antimony is an excellent conductor of electricity, it dissolves the anode freely, yields plenty of bright reguline metal if the battery power is sufficiently weak, and its depositing power does not deteriorate by exposure to light or the atmosphere, but it appears to be gradually exhausted by working; it is also decomposed more or less rapidly by zinc, tin, lead, iron, brass, and german silver, each of which coat themselves in it with antimony by simple immersion, and articles immersed in it require to be washed with hydrochloric acid before washing them with water, otherwise the latter decomposes the adhering liquid and covers them with a white insoluble powder.

98. The mixed chlorides of antimony and ammonia form a very good depositing

liquid. It may be formed either by the battery process, by mixing one measure of a saturated solution of sal-ammoniac with one measure of hydrochloric acid, and working antimony into it by means of a battery and a large antimony anode; or by simply mixing together equal measures of a saturated solution of sal-ammoniac and commercial chloride of antimony. This solution conducts easily, yields its metal freely and of good quality, and does not act so strongly upon base metals as chloride of antimony alone; but in other respects it is similar to the chloride. The mixed chlorides of antimony and manganese, or of antimony and bismuth, yield a reguline deposit easily, but do not appear to possess any special advantages.

99. The potassio-tartrate of antimony is a salt not very soluble in water; its aqueous solution is a very bad conductor of electricity, and is not to be compared to the chloride for depositing purposes; we have never been able, either with strong or weak batteries, to deposit from it anything better than a small quantity of antimony in the state of a perfectly black powder;—on the other hand its solution in hydrochloric acid (which dissolves it very freely), or hydrochloric acid and water, is by far the best solution for depositing antimony that we have tried; it is a most excellent conductor of electricity; it is not impaired by long working or exposure to light or the atmosphere (we have deposited antimony from it constantly during many months); it will bear a very great amount of battery power without the deposit passing into the state of a loose powder; it deposits reguline metal very rapidly and in great thickness; we have obtained such deposits from it upwards of two inches in thickness; articles immersed in it wash clean in water alone without the previous use of hydrochloric acid; it may be made by mixing together about two pounds of water, four pounds of hydrochloric acid, and eight pounds of potassio-tartrate of antimony; a greater proportion of water may be used if desired.

100. Both the black and red sulphides of antimony dissolve in cold hydro-sulphate of ammonia, and the resulting solutions conduct very freely with an antimony anode and one pair of Smee's battery, but yield no deposit of metal even with a battery of twenty-five pairs intensity. Aqueous solutions either of caustic potash, tartrate of potash, or oxalate of potash, scarcely conduct at all with an anode of antimony, and a battery consisting of one or two pairs. Cyanide of antimony dissolved in a solution of cyanide of potassium has been proposed as a depositing liquid, but we have found a solution of cyanide of potassium to be a very bad conductor with an anode of antimony.

101. Antimony is one of the easiest metals to deposit in the reguline state; its appearance when deposited, from the chloride solutions and from the solution of the potassio-tartrate in hydrochloric acid, is very beautiful, and when deposited slowly, it has much the appearance of highly-polished steel. Some of its properties when thus deposited are very peculiar and interesting, especially with regard to heat:—"If, during any part of the time the deposit is progressing, the deposited antimony be taken out and struck gently or rubbed with any hard substance, such as metal or glass, an explosion occurs, accompanied with a small cloud of white vapour, sometimes with a flash of light, and nearly always with considerable heat, sufficient to burn one's fingers, melt gutta-percha, burn paper, and even scorch deal wood quite brown, especially if the deposit is thick; and invariably accompanied by fracture of the deposited metal; sometimes, if the process of deposition has been interrupted and the deposited metal is not homogeneous, the fracture extended quite through the metal to upwards of one-eighth of an inch in depth. This phenomenon has been observed many times both

before and since its first publication; in several instances the explosion took place even in the liquid, by striking the deposit against the glass containing vessel; and in one instance it occurred after the metal had been well washed with dilute hydrochloric acid, dried, and had remained out of the liquid several hours."

On one occasion, a deposit had been well washed, dried, and out of the solution many hours, and a friend, in course of conversation, was unconsciously breaking small portions off it with his fingers, when it became suddenly heated and exploded, causing a slight noise like the lighting of a congreve match, and burning his fingers. On other occasions a deposit has been progressing, and has been removed an instant for examination, and the battery liquid strengthened by the addition of acid; upon examining the deposit a few hours afterwards, it has been found cracked in various directions, as if an explosion had occurred in the interval, although the apparatus has been undisturbed. A French writer has suggested that this deposit is a compound of antimony and hydrogen; and from the fact that the explosions occurred when the metal was depositing rather rapidly, we are inclined to think this explanation correct; the extra power, as we have seen in other cases of hydrogen deposit, which being in its nascent state instead of being evolved, might combine with the metal and form an explosive compound. Another suggestion we would make is, that the metal is deposited in a peculiar condition of unequal mechanical tension, similar to that of unannealed glass, and that, by breaking, the closer aggregation of the particles may develop light and heat.

102. Another peculiarity in depositing antimony from the potassio-tartrate solution is, that if the solution be a very dense one, and the process long continued without disturbance of the liquid; the deposit occurring upon the cathode will slowly spread out in the form of a thin sheet upon the surface of the liquid, until it touches the anode; whilst the deposit beneath progresses very slowly. We have a button of antimony formed in this way upon a vertical copper wire, one and five-eighths inches in diameter, the deposit beneath the surface of the liquid having been only half-an-inch thick; it occupied about eighteen days with a small one pair Smee's battery in forming. Deposits of antimony formed in the above solution do not spread over blackleaded surfaces of gutta-percha, nor do they adhere with any great degree of firmness to copper, brass, or iron.

103. *Bismuth Salts.*—The most usual compounds of bismuth are the chloride, mononitrate (pearl white), and ternitrate. The chloride is formed by digesting bismuth filings a long time in a warm place with hydrochloric acid. The mononitrate is formed by dissolving bismuth to saturation in warm dilute nitric acid, and then adding a large quantity, say fifty or a hundred times its volume of water; the precipitate produced, when well washed with water, is the substance required. The ternitrate is formed by dissolving the metal in hot nitric acid, evaporating the solution, and leaving it in a cold place to crystallize. Bismuth may easily be deposited from a solution formed by dissolving either mononitrate or ternitrate of bismuth in dilute nitric acid, but requires an exceedingly feeble current to deposit it in a reguline state; its appearance when so deposited is very beautiful, white with a faint pinkish tint, and with a fine silky lustre; it does not spread over blackleaded surfaces of gutta-percha in this liquid. A bismuth anode does not dissolve readily in a hot solution of cyanide of potassium.

104. *Zinc Salts.*—There are a variety of salts of this metal in ordinary use, the most common of which are the sulphate, chloride, nitrate, and acetate. The sulphate

may be formed by dissolving zinc to saturation in a mixture of sulphuric acid and water, filtering and evaporating the liquid, and setting it in a cold place to crystallize. The chloride is formed by saturating hydrochloric acid with zinc, filtering, evaporating, and crystallizing. The acetate may be made either by dissolving zinc in strong acetic acid to saturation, then evaporating and crystallizing the solution; or by adding a solution of acetate of lead to a solution of sulphate of zinc as long as it produces a precipitate; filter, evaporate, and crystallize the liquid.

105. *Zinc Solution*.—The sulphate of zinc solution for depositing may be formed by dissolving two pounds of the salt in a gallon of water, and filtering the mixture; but the best sulphate depositing solution we have used has been the spent battery liquid taken from a cell of a Smee's battery, in which there had occurred a very good deposit of zinc upon the platinized silver plate; but with this and with other solutions of zinc there is a great tendency to the evolution of hydrogen gas at the cathode during deposition; they require, therefore, to be worked very carefully and with very feeble battery power. Zinc may be readily deposited, either by the single cell or by the battery process, from a neutral solution of the sulphate; but the single cell is less adapted for its deposition than the battery, because the acid, set free by the deposition of the metal, re-acts upon the deposit, and diminishes its cohesion. The other solutions, such as the chloride, nitrate, acetate, or the various double salts of zinc, with ammonia, or potash, do not appear to possess any general advantages over the sulphate.

Amongst other liquids, that of cyanide of zinc dissolved in a solution of cyanide of potassium has been recommended; but it is a bad conductor with a zinc anode, and requires to be used hot to make it conduct at all freely, or make the anode dissolve. This might easily have been foreseen from a knowledge of the fact, that the affinity of cyanogen for all, or nearly all, the base metals is comparatively feeble. We have found by experiment that a solution of cyanide of potassium will dissolve only about one half as much cyanide of zinc as it will of cyanide of copper. Zinc oxide dissolves somewhat freely in a boiling solution of cyanide of potassium. Cyanide of zinc dissolves freely in a solution of sesquicarbonate of ammonia. Ferrocyanide of zinc is but feebly soluble in a boiling solution either of ferrocyanide (yellow prussiate), or of ferrid-cyanide (red prussiate) of potassium, but it is freely soluble in a boiling solution of cyanide of potassium. Zinc deposits may be made to spread over blackleaded surfaces by the battery process.

106. *Cadmium Solution*.—A patent was taken out March 19, 1849, by Messrs. Russell and Woolrich for the electro-deposition of cadmium, and the following is their description of the process:—"Take cadmium and dissolve it in nitric acid diluted with five or six times its bulk of water, at a temperature of about 80° or 100° Fah., adding the dilute acid by degrees until the metal is all dissolved; to this solution of cadmium a solution of carbonate of soda (made by dissolving one pound of the ordinary crystals of soda in one gallon of water) is to be added until the cadmium is all precipitated; the precipitate thus obtained is to be washed four or five times with tepid water; next add as much of a solution of cyanide of potassium as will dissolve the precipitate; after which, one-tenth more of the solution of cyanide of potassium is to be added, to form *free* cyanide. The strength of this solution may vary, but the patentees prefer a solution containing six troy ounces of metal to the gallon. The solution is worked at about 100° Fah., with a plate of cadmium as an anode."

107. *Tin Salts*.—The most common salts of tin are the peroxide and proto-

chloride; in addition to these there are two others used extensively in Manchester, and the cotton printing districts, viz., the bichloride and the stannate of soda, *i.e.*, oxide of tin combined with caustic soda. Peroxide of tin is formed by dissolving protochloride of tin in water containing a few drops of hydrochloric acid, and then adding liquid ammonia or a solution of carbonate of potash as long as a precipitate can be produced; the precipitated peroxide of tin should be washed and dried. Protochloride of tin is easily made by adding grain tin to strong hydrochloric acid, and keeping it at 150° or 200° Fah., until gas ceases to be evolved from the metal; the resulting solution should then be evaporated and crystallized. Aqueous bichloride of tin may be made by dissolving tin in aqua regia not containing too much nitric acid; a mixture of nitric acid with sal-ammoniac or common salt may likewise be used. Stannate of potash may be formed by fusing together one equivalent (75 parts) of freshly precipitated peroxide of tin, and one equivalent either of caustic potash (56·2 parts), or of crystallized carbonate of potash (87·2 parts).

108. *Tin Solutions.*—M. Roselau has patented the following liquids for the deposition of tin :—

1st. For simple immersion or wash process, which may be used for small articles generally :—dissolve 17½ ounces of ammoniacal alum in 22 pounds of boiling water, and, when dissolved, add one ounce of protochloride of tin; the articles to be coated should be well cleaned and then immersed in the liquid, and moved about in it until they are sufficiently white.

2nd. For depositing tin upon lead, iron, steel, copper, or brass, by connecting the articles with a piece of zinc and immersing them in the solution :—dissolve 10½ ounces of bitartrate of potash in 17½ pints of water, then add three-quarters of an ounce of protochloride of tin, and boil it a few minutes; the articles to be coated are immersed in the solution in contact with a piece of zinc of proportionate size.

3rd. For coating zinc, iron, copper, and many other metals by the battery process :—dissolve 11 ounces of pyrophosphate of potash or soda in 17½ pounds of water, then add 4½ ounces of protochloride of tin, and operate by the battery process with an anode of tin. By this process M. Roselau states that he can tin metals beautifully and to any thickness. Pyrophosphate of soda is easily formed by heating to redness the common diphosphate of soda.

109. A protochloride of tin-depositing liquid may easily be formed by dissolving the ordinary commercial protochloride in water, and adding a little hydrochloric acid to remove any cloudiness or white precipitate which may be formed; a similar liquid may be made by the battery process, by passing a current through dilute hydrochloric acid by means of a large tin anode until sufficient metal is dissolved. This or any other from chloride of tin is not a good solution to obtain reguline metal from; it has a very great tendency to deposit the tin in the form of long crystalline needles, of a fern-like appearance, which often project from the corners and edges of the cathode to a distance of upwards of half an inch. A solution composed of eleven ounces of water, one ounce of hydrochloric acid, and eighty grains of protochloride of tin admits of this effect being produced in a striking degree; nearly all the compounds of tin, and especially those formed with mineral acids, exhibit this tendency in a greater or less degree when acted upon by electrolysis, rendering the deposition of tin in thick layers of fine white coherent metal a matter of considerable difficulty.

110. The stannate of potash solution is easily formed either by dissolving the crystallized salt in water, or by dissolving freshly precipitated peroxide of tin (109)

whilst still moist, in a boiling solution of caustic potash. It may also be easily formed by the battery process, by passing a strong current of electricity by a large tin anode through a strong and boiling solution of caustic potash, until the immersed cathode receives a free white deposit. This solution, if worked at 150° Fah., yields a good deposit of fine white metal; but it decomposes by exposure to the atmosphere, and soon deposits all its metal as oxide of tin, at the bottom of the vessel. A solution of cyanide of potassium and tin has been proposed as a depositing liquid; but it is a bad conductor with a tin anode, even if hot, and does not dissolve tin freely.

111. Mr. Joseph Steele coats zinc, iron, steel, copper, and brass, with tin, in his patent solution, by the battery process, thus:—dissolve 60 pounds of common soda, 15 pounds of pearl-ash, 5 pounds of caustic potash, and 2 ounces of cyanide of potassium, in 75 gallons of water, at 75° Fah., and filter the resulting solution; then add 2 ounces of acetate of zinc, and 16 pounds of bioxide of tin; stir the resulting solution until all is dissolved; it is then ready for use. Work it by the battery process with an anode of zinc or tin, and with the liquid at 75° Fah.

112. **Electrical Relations of Tin and Iron.**—Tin is feebly negative to iron at all temperatures between 62° and 203° Fah. in distilled water, and positive to it at 212° Fah. It is positive to iron at all temperatures between 62° and 212° Fah. in a saturated solution of boracic acid; also the same between those temperatures in a strong solution of phosphoric acid in distilled water; or in one measure of oil of vitriol mixed with either nine or ninety-six measures of distilled water; or in a mixture of one measure of this acid, and 192 measures of distilled water, from 73° to 158° Fah., and negative to iron above that to 212° Fah.; it is positive to iron from 72° to 212° Fah. in a mixture of equal measures of hydrochloric acid and water; it is negative to iron from 70° to 77° Fah., and positive above that to 212° Fah., in a mixture of one measure of hydrochloric acid and nine measures of distilled water; it is negative to iron from 70° to 212° Fah. in a mixture of one measure of hydrochloric acid, and ninety measures of distilled water, and positive to iron from 68° to 212° Fah. in one measure of hydrofluoric acid and nine measures of water; it is positive to iron in one measure of nitric acid and nine measures of water, from 70° to 111° Fah., and negative from 111° to 212° Fah.; and it is positive to iron from 82° to 212° Fah. in a mixture of one measure of nitric acid and ninety-six measures of water.

113. *Lead Salts.*—The most common salts of lead are the nitrate and the acetate. The nitrate is formed by dissolving lead in dilute nitric acid, taking care that no more lead is added than the acid will dissolve; the resulting solution must be filtered, evaporated, and crystallized; it is a hard, white salt, soluble in water. Acetate of lead is made by digesting oxide of lead in vinegar or acetic acid; filtering, evaporating, and crystallising the liquid; it is soluble in water.

114. *Lead Solution.*—Lead may be deposited from an aqueous solution, either of nitrate or acetate of lead, or from a solution of plumbit of potash,—the latter is formed by dissolving litharge in a boiling solution of caustic potash; zinc and tin articles (but not iron ones) decompose this liquid and coat themselves with lead in it by simple immersion. It is difficult to deposit any considerable thickness of reguline metal from either of these liquids.

115. *Salts of Iron.*—Among the salts of iron in most common use, are the sulphate, chloride, and nitrate; they may be respectively formed by dissolving metallic iron in dilute sulphuric, hydrochloric, or nitric acids, evaporating and crystallising the solution as much as possible out of contact with the air.

116. *Iron Solutions.*—Iron may be reduced from a solution of its protosulphate (green copperas), made by dissolving metallic iron in dilute sulphuric acid; or from its protochloride, which is preferable, and which is made by dissolving iron in hydrochloric acid. We have deposited it in the state of reguline white metal, by passing a current of considerable intensity (15 or 20 pairs), for one hour, through an anode of iron immersed in a saturated aqueous solution of sal-ammoniac; its appearance when deposited from this liquid is rather white, with an appearance very similar to that of freshly broken cast iron. By the same means it may also be deposited, using a saturated solution, either of carbonate of ammonia, acetate of ammonia, or acetate of potash. We have also obtained good metal from a saturated aqueous solution of a mixture of two parts of protosulphate of iron and one part of sal-ammoniac. We have deposited it from an aqueous solution of ferrate of potash, which may be formed either by igniting peroxide of iron (crocus) very strongly for some minutes with caustic potash and saltpetre; or we may make a very strong solution of caustic potash, immerse in it a large iron or steel anode, and a small copper or platinum cathode, and pass a strong current from fifteen or twenty pairs of Smee's batteries through it until it acquires a deep amethyst or purple colour; by that time the cathode will have obtained a coating of iron, which will be in the state of a dark powder if the power has been too great, or it will have the appearance of white cast iron, or intermediate between that and the appearance of reguline deposited zinc, if the power has been sufficiently weak; this solution rapidly decomposes without any very apparent cause, becoming colourless, and depositing all its metal in the state of peroxide at the bottom of the vessel. Iron may be very easily deposited from its sulphate, thus:—dissolve a little crystalline sulphate of iron in water, and add a few drops of sulphuric acid to the solution; one pair of Smee's batteries may be used to deposit the iron upon copper or brass. The metal in this pure state has a very bright and beautiful silvery appearance. An aqueous solution of cyanide of potassium is a very bad conductor with an iron anode, even if it be maintained hot.

117. *Cobalt Solution.*—A solution of protochloride of cobalt may be easily formed by digesting commercial brown oxide of cobalt in hot hydrochloric acid; it is a deep blue liquid, but changes to a reddish-brown colour on the addition of water; by slow cooling, fine red crystals of the chloride may be obtained. We have not tried this liquid for electro-deposition.

119. *Nickel Solutions.*—The nitrate of nickel solution may be formed by dissolving nickel in nitric acid, slightly diluted with water, and, when dissolved, diluting it with much more water; it is a solution which does not yield its metal freely. We have deposited nickel in the state of reguline white metal from a solution of the double chloride of nickel and ammonia, by making a lump of metallic nickel the anode in a strong aqueous solution of sal-ammoniac, and passing a strong current of electricity through it for several hours, until the liquid acquired a pale greenish-blue colour. We have also obtained a similar deposit by treating a solution of one part of arseniate of potash and five parts water in a similar manner. It has also been deposited from a solution formed by dissolving pure nickel in nitric acid, then diluting and precipitating it by a solution of carbonate of potash, or cyanide of potassium; washing the precipitate and dissolving it nearly to saturation in a solution of cyanide of potassium, and operating upon this liquid, by the battery process, with an anode of pure metal. Its appearance, when deposited from this solution, is said to be nearly equal in whiteness to silver, and its deposition has been proposed to be applied to the production of an inferior class of plated articles.

119. *Copper Salts.*—The ordinary salts of copper are the protoxide (black oxide of copper), sulphate, chloride, nitrate, acetate, and cyanide. To make the protoxide, heat either the carbonate or nitrate to a moderate red heat, or the sulphate to intense redness. The sulphate may be formed by heating one equivalent (31·7 parts) of copper filings, and at most two equivalents (98 parts) of oil of vitriol, until the residue is quite dry, then dissolving the product in water, filtering, evaporating, and crystallizing the solution; but it is much more convenient to purchase it, on account of its low price (fourpence to sixpence per pound). The chloride and nitrate may be formed, the first by dissolving copper in aqua regia, or by saturating hydrochloric acid with protoxide of copper, and evaporating and crystallizing the liquids; and the second, by dissolving copper in nitric acid, evaporating and crystallizing the solution. Acetate of copper is most conveniently purchased; its commercial name is crystallized verdigris. Cyanide of copper may be made by adding a solution of cyanide of potassium to a solution of sulphate of copper (each liquid being cold), as long as a precipitate can be produced; filtering, and washing the precipitate, which is the required compound; it is a fine powder of a pale green colour. In the operation a large quantity of cyanogen gas is evolved, which if freely inhaled is dangerous to the health; in consequence also of this escape of cyanogen the cyanide of copper is not a *proto*cyanide, but contains two equivalents of cyanogen for every three equivalents of copper; it is freely soluble in a solution of cyanide of potassium; it is also soluble in aqueous ammonia and in a solution of carbonate of ammonia.¶The proportions of materials we have used in making it has been 65 parts of cyanide of potassium and 125 parts of sulphate of copper. The precipitating solution is invariably greenish-blue, and contains much copper after all precipitation ceases, but no use has hitherto been made of this remainder.

120. *Copper Solutions.*—Copper may be easily deposited either by simple immersion (wash process), by the single cell, or by the battery process. According to Keinsch, iron may be coated with a durable and polishable layer of copper of any thickness (?). The process by simple immersion is thus:—mix together one measure of hydrochloric acid, three measures of water, and a few drops of a solution of sulphate of copper; clean and immerse the iron; wash it, rub it with the copper solution, and re-immerse it repeatedly, adding a few drops of the copper solution occasionally. In depositing copper by the single cell process, a nearly saturated solution of sulphate of copper answers very well; but for the battery process an excellent solution may be made by dissolving four parts, by weight, of finely divided sulphate of copper (best quality), and one part of sulphuric acid, in about eighteen or twenty parts of water, and then filtering it; neither of these solutions, however, is fit to deposit copper upon iron, steel, or zinc; because the electrical relations of these metals in the solution are unsuitable; these metals decompose the solutions rapidly, and deposit the copper upon themselves by simple immersion. To effect an adhesive deposit of copper upon iron, a solution composed of cyanide of copper dissolved in a solution of cyanide of potassium may be used. It is formed thus:—dissolve cyanide of copper to saturation in water containing about two pounds of water to the gallon, and then add about one-eighth more of the cyanide of potassium solution to form *free* cyanide; the liquid is then ready, and should be used at a temperature of about 150° Fah.

121. Copper is electro-positive to iron in the following liquids at 60° Fah.:—powerfully in a solution of hydrosulphuret of ammonia; feebly in a saturated solution of ammonia; in a solution of oxide of copper in liquid ammonia; in aqueous

ammonia, or in a saturated solution of ferrocyanide of potassium, each but for a short time—it then becomes negative; in a saturated solution of bichromate of potash; in a strong aqueous solution of sulphide of potassium, it is increasingly positive up to the boiling point of the liquid. This last liquid has a similar effect on brass.

122. *Brassing Solutions.*—Much interest and importance was long attached to the discovery of solutions whereby alloys, and especially brass, might be deposited in the reguline state, and various liquids have been used and patented for this purpose. M. de Ruolz, in 1841, deposited brass from the cyanides of zinc and copper, dissolved together in a solution of cyanide of potassium. Copper articles may be superficially brassed by boiling them in a solution of bitartrate of potash with zinc amalgam, or by boiling them in dilute hydrochloric acid with some bitartaite of potash and zinc amalgam.

123. The same object was effected by Russell and Woolrich's patent, dated March 19, 1849, which is as follows:—Take 10 pounds of acetate of copper, 1 pound of acetate of zinc, 10 pounds of acetate of potash, and 5 gallons of hot water; dissolve the salts in the water, then add as much of a solution of cyanide of potassium as will precipitate it and will re-dissolve the precipitate, and in addition add about one-tenth more of cyanide of potassium in excess. Use a brass anode, or else two anodes, one of zinc and one of copper.

124. Joseph Steele's patent, dated August 9, 1850.—Dissolve 2¼ pounds of American potash in 6 gallons of hot water, and filter the solution; also dissolve 2¼ ounces of acetate of copper in half a pint of strong liquid ammonia, and add it to the first solution with stirring; also add 4 or 5 ounces of sulphate of zinc, and stir till dissolved; and, finally, add 2 ounces of cyanide of potassium, filter the resulting solution, and use it at 100° Fah., with a brass anode. To obtain a dark coloured brass add more acetate of copper; and to obtain it of a lighter colour, add more sulphate of zinc.

125. Salzede's patent, dated September 30, 1847.—Take 5000 parts of water, dissolve 12 parts of cyanide of potassium in 120 parts of it, then add 610 parts of sub-carbonate of potash, 48 parts of sulphate of zinc, and 25 parts of chloride of copper to the remainder of the water, and heat the mixture from 144° to 172° Fah.; and when the salts are entirely dissolved, add 305 parts of nitrate of ammonia, allow the liquid to remain undisturbed for twenty hours, and then add the solution of cyanide of potassium; allow it to remain again till clear, and then draw off the transparent liquid, which is ready for use; work it with a large brass anode and a strong battery. Another liquid which he uses for brassing consists of 5000 parts of water, 500 parts of sub-carbonate of potash, 35 parts of sulphate of zinc, 15 parts of chloride of copper, and 50 parts of cyanide of potassium. For a bronzing solution he uses 25 parts of chloride of tin in place of the sulphate of zinc of the first brassing liquid, and proceeds as with that process; for a second bronzing solution he uses 12 parts of chloride of tin in place of the sulphate of zinc, of the second brassing liquid, using the solution from 77° to 97° Fah.

126. Brunel, Bisson, and Gaugain's formula.—Required fifty parts of carbonate of potash, 2 parts of chloride of copper, 4 parts of sulphate of zinc, and 25 parts of nitrate of ammonia, dissolved together in cold water, and used with a brass anode and a strong battery.

127. Morris and Johnson's patent, dated December 11, 1852.—According to this process, dissolve 1 pound of cyanide of potassium, 1 pound of commercial

carbonate of ammonia, 2 ounces of cyanide of copper, and 1 ounce of cyanide of zinc, in 1 gallon of water, and use the solution at 150° Fah., with a large anode of brass and a powerful battery. Or a solution may be taken of 1 pound of cyanide of potassium and 1 pound of carbonate of ammonia, dissolved in 1 gallon of water, and saturated with copper and zinc to the requisite degree by means of a strong battery, a large brass anode, and small cathode, until the latter receives a good deposit of brass, the solution being at a temperature of 150° Fah. To increase the proportion of copper in the deposit, either add cyanide of potassium, or raise the temperature of the liquid; and to increase the proportion of zinc in it, either add carbonate of ammonia, or lower the temperature.

129. Of the numerous solutions that have been tried for depositing brass, the one just mentioned is much the best. By it reguline and thick deposits of brass, of uniform colour, and of any desired composition, may be obtained. It is not an expensive liquid; it acts with average strength upon the anode; it holds a sufficient quantity of the alloy in solution; it conducts electricity with moderate facility; and it yields its metal in the reguline state very uniformly; while it bears a great variation in the electric power without injury to the character of the deposit: is, therefore, very easily managed; does not act perceptibly upon cast iron, wrought iron, steel, or even zinc, so as to injure the adhesion of the deposit; and it is not decomposed by exposure to the atmosphere, to light, or heat, in such a way as to effect its depositing power. Its defects are, that it requires to be worked hot, and with considerable battery power, in order to make the anode dissolve rapidly, the solution conduct copiously, and to cause a rapid deposit; while it evolves an abundance of gas at the cathode when working, whether the solution is hot or cold, which indicates that part of the battery power is expended in decomposing the water of the liquid, depositing its hydrogen with the metalic alloy, and oxidizing the solution. But all the brassing solutions are, theoretically considered, very imperfect.

129. *Mercury Solutions.*—The ordinary compounds of mercury are the bioxide (red precipitate), bisulphide (vermilion), bichloride (corrosive sublimate), nitrate, and bicyanide. The nitrate is formed by dissolving mercury in nitric acid diluted with three times its bulk of water, the mixture being cold, and no more metal added than the acid will dissolve. The solution when diluted with water may be used for depositing by the battery process, a layer of mercury at the bottom of the liquid being used as the anode, and connected with the battery by a platinum wire passing through a tube of glass or gutta-percha. The bicyanide is made by taking eight parts of prussian blue and 16 parts of peroxide of mercury, both in the state of fine powder, in 80 parts of water, boiling the mixture for about a quarter of an hour, filtering the liquid, and evaporating, and crystallizing the solution; the resulting salt is the bicyanide, and to form it into a solution fit for depositing, it must be dissolved in a solution of cyanide of potassium; the solution may be used with a mercury anode and battery as already described.

130. *Silver Salts.*—The most common salts of silver are the oxide, chloride, nitrate, and cyanide;' the oxide, chloride, and cyanide, are sold retail at about seven shillings per ounce, and the nitrate at five shillings per ounce. Oxide of silver is prepared by adding a solution of caustic potash to a solution of nitrate of silver, as long as a precipitate can be produced; the brown precipitate, when washed and dried, is oxide of silver. Chloride of silver is made by adding either hydrochloric acid or a solution of common salts to a solution of nitrate of silver, until a precipitate ceases to be formed;

the white precipitate of chloride of silver should be washed dried, and preserved out of the influence of light. Nitrate of silver is easily formed by adding grain silver, in small quantities at a time, to a warm mixture of one measure of distilled water and four measures of the strongest nitric acid; if the liquid is too hot, or too much silver is added at a time, the action will be very strong, and loss of materials may be occasioned; in such a case add a small quantity of cold distilled water. When the liquid ceases to dissolve more metal, it should be evaporated and crystallized, or else kept, protected from the light, until required to be used; nearly all the compounds of silver are formed by means of this salt. Acetate of silver is made either by adding a solution of acetate of potash or acetate of soda, to a solution of nitrate of silver, as long as a precipitate occurs, or by digesting the oxide or the carbonate of silver in hot and strong acetic acid; it is freely dissolved by a solution of cyanide of potassium. Cyanide of silver is generally prepared by adding a solution of cyanide of potassium to one of nitrate of silver as long as a precipitate occurs; the white precipitate, which is cyanide of silver, is insoluble in water, and is not perceptibly soluble in commercial hydrocyanic acid; it dissolves very freely in a solution of cyanide of ammonium, potassium, or sodium, and in hyposulphite of soda; it is also said to be soluble in solutions of ammonia, carbonate of ammonia, sal-ammoniac, nitrate of ammonia, and ferrocyanide of potassium.

131. M. Brandeley, a French experimentalist, makes the following remarks upon the preparation of cyanide of silver:—"To obtain a beautiful and easy deposit of silver we choose, among all the salts of silver, the cyanide, as giving the best results; but as the dealers sell this at a high price, both amateurs and manufacturers reject it. Others, for the sake of economy in procuring it, purchase hydrocyanic acid; but this also is of too high a price, independently of our being obliged to use it immediately, it being both dangerous and difficult to preserve, as the air and light decompose it. If we take commercial hydrocyanic acid which has been prepared fifteen days, and pour it into a solution of nitrate of silver, consisting of one part of the nitrate to six parts of water, cyanide of silver is formed, but it is more or less yellow, and much ammonia and hydrocyanic gases are evolved. On the other hand, if we make a solution of cyanide of potassium, filter it, and dissolve cyanide of silver in it, immediately the solution, which was clear and colourless, becomes troubled and black, and betrays an odour of ammonia and hydrocyanic acid. This odour will continue as long as the solution exists, and a deposit of carbon will be found in the containing vessel. This sediment arises from the decomposition of one part of the cyanide of potassium, caused by the presence of the cyanide of silver. Having occasion to use considerable quantities of the cyanide of silver, I dissolve pure silver in pure nitric acid, evaporate just to dryness, dissolve the nitrate of silver thus obtained in distilled water, and pass hydrocyanic (prussic acid) gas through it, from a mixture of pounded ferrocyanide of potassium and sulphuric acid diluted with twice its weight of water, continuing thus as long as a precipitate is formed. Wash the cyanide of silver, and preserve it below water, away from the light. Thus precipitated, the salt dissolves without residuum or colour, and gives splendid results."

With regard to this process we may remark, that six parts of sulphuric acid should be mixed with from thirty to forty parts of water, and the mixture allowed to cool; then put into a glass vessel (Fig. 30), together with ten parts of coarsely-powdered ferrocyanide of potassium; and heat applied until gas is evolved from the mixture, and continued as long as gas is evolved, or as long as a precipitate is produced in the silver solution, the gas being passed into the liquid by a suitable tube (see Fig 31). This process may yield a purer product than when the nitrate solution is precipitated by cyanide of potassium; but it cannot be very economical, because only half of the cyanogen of the ferrocyanide passes over as hydrocyanic acid; the remainder is left behind, and is contained in the yellowish-white residuum in the gas-generating vessel.

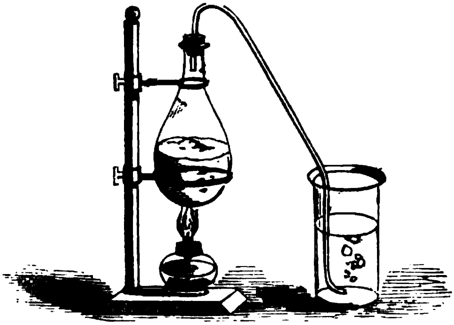

Fig. 31.

132. *Silver Solutions.*—Silver has been deposited by the ordinary dipping or wash process, by the single cell, and by the battery process. The following are recipes for solutions taken from various sources, adapted for silvering articles by the simple immersion or wash process, chiefly applicable to small articles, such as pins, buttons, buckles, coffin-nails, hooks and eyes, &c., where only a very thin coating of silver is required. The solutions in the proportions indicated, are used by adding a small quantity of water, sufficient to form the ingredients into a pasty liquid of the consistence of cream, stirring the articles thoroughly about in it, or rubbing them over with it until they have acquired the desired degree of whiteness:—1st, take equal parts of chloride of silver and bitartrate of potash; 2nd, take chloride of silver one part, alum two parts, common salt eight parts, and tartar eight parts; 3rd, take chloride of silver one part, prepared chalk one part, common salt one and a quarter parts, and pearl-ash three parts; 4th, a "novargent" solution for re-silvering old plated goods, consists of one hundred parts of hyposulphite of soda and chloride, or any other salt of silver, fifteen parts. Compounds of this description are also used for silvering clock-faces, thermometer and barometer plates, and many other articles of copper and brass.

133. *Silvering by Immersing.*—Mr. Joseph Steele took out a patent, dated August 9, 1850, for silvering articles by immersing them in a silver solution in contact with a piece of zinc of proper size. The process is as follows:—Dissolve four ounces of pure silver in twenty ounces of nitric acid; also dissolve separately one and a half pounds of common salt in one and a half gallons of water; mix the two solutions together, allow the mixture to remain till clear, pour away the clear liquid, and wash the precipitate, which is chloride of silver; next fuse together twenty-four ounces of ferrocyanide of potassium and twelve ounces of carbonate of potash, and when the mass is cold, add it, together with the chloride of silver, to one gallon and a half of water; boil the mixture, and filter it; it is then ready for use.

134. *Silvering Solution for Battery Process.*—Many solutions have been proposed and tried for depositing silver by the battery process, but none have stood the test of time and experience like the one composed of double cyanide of silver and potassium dissolved in water, and a little *free* cyanide of potassium added. It may be made of various strengths, from half-an-ounce of silver to the gallon of water, to two, four, six, or more ounces; and from an ounce of cyanide of potassium to several pounds per gallon, and still be effective in working. The formula of M. de Ruolz is as follows:—dissolve one part of cyanide of silver and ten parts of cyanide of potassium in one

hundred parts of water, and dilute the resulting liquid with water to the required strength.

135. *Silver Plating Solution.*—The following is the most practical method of making a large quantity of the ordinary cyanide of silver plating liquid:—Take four parts of grain silver, add it, in small portions at a time, to a warm mixure of about five parts by weight of strong commercial nitric acid (the acid varies greatly in strength), and one part of water, contained either in a glass or stoneware vessel. Gas will be evolved from the surfaces of the pieces of silver, and brown fumes of nitrous acid will arise from the mixture, which should be conveyed out of the apartment by means of the chimney. The action should be maintained moderate and uniform, and if it should become too strong, a little cold water should be added, and the mixture kept more cool; when the whole of the metal is dissolved, apply a greater heat, and evaporate the solution nearly to dryness, which will drive off any excess of acid that may be present; the resulting salt, nitrate of silver, may then be dissolved in a large quantity of water, in the proportion of half a gallon (more or less) to each ounce of the silver used; at the same time a solution should be made of from 3 to 3¼ parts (according to its quality) of cyanide of potassium in 30 or 40 parts of water, which is to be added gradually to the solution of nitrate of silver as long as it produces a precipitate; if too much be added, it will cause some of the precipitate to re-dissolve and be wasted; it will also make the liquid appear clear where it passes; in such a case the liquid should be stirred, then allowed to settle clear, and a small quantity of nitrate of silver dissolved in *distilled* water should be added as long as it produces a white cloud. By conducting the operation in a glass vessel, adding the liquid towards the latter period in small quantities at a time, and at intervals of a few minutes each, with gentle stirring immediately upon each addition, carefully observing when it ceases to produce a precipitate, the point of neutralisation may be very accurately determined. The liquid must now be allowed to remain undisturbed until quite clear, the clear portion poured steadily away from the precipitate of cyanide of silver, and the precipitate washed five or six times in a large quantity of water, by simply adding the water briskly to it, allowing it to settle, and then pouring away the clear portion. Next dissolve from 3 to 3¼ parts (according to its quality) of cyanide of potassium in 20 parts of water, adding it in portions at a time to the wet cyanide of silver, with free stirring, until the whole is dissolved, then add about 3 parts more of cyanide of potassium to form *free* cyanide, and sufficient water to reduce the whole to the proportion of about one ounce of silver to the gallon; finally, when all the free cyanide is dissolved, filter the solution through a piece of unglazed calico. On the small scale, distilled water is used in the various parts of the process, except the washing; but, on the large scale, clean rain water or spring water is used in all the operations.

136. *Another Solution.*—The cyanide of silver plating solution may be made by other modifications of the chemical method than the one described; for instance, some depositors make the solutions by adding oxide, carbonate, or even chloride of silver to a solution of cyanide of potassium, as long as it will dissolve, and then adding an amount of free cyanide; by this process the depositor is enabled to use caustic potash, carbonate of potash, hydrochloric acid, or common salt, instead of cyanide of potassium, for precipitating the nitrate of silver; nevertheless it still requires two equivalents of cyanide of potassium to be used as before, viz., one to convert the salt of silver into cyanide, and the other to dissolve the cyanide of silver formed, because in all such cases, according to the researches of Messrs. Glassford and Napier ("Philoso-

phical Magazine," 1844), when any salt of silver is added to a solution of cyanide of potassium, it is first converted into cyanide of silver at the expense of one portion of the cyanide of potassium; it then combines with the remaining cyanide to form double cyanide of silver and potassium, which dissolves in the water; therefore, by this modification of the chemical method, no cyanide of potassium is saved, and the carbonate of potash, hydrochloric acid, &c., are wasted. This modification has a still greater disadvantage; it introduces substances into the depositing liquid which are injurious. We have before said (90) that a good depositing solution should dissolve the anode freely, hold abundance of metal in solution, and not act chemically upon base metals, because it is such metals we generally wish to coat; now, if instead of cyanide of silver we add oxide of silver to the cyanide of potassium liquid, it converts part of the cyanide into caustic potash; if we add carbonate of silver, it converts it into carbonate of potash; and if chloride of silver, it converts it into chloride of potassium; and each of these substances, especially the last, diminishes the action of the liquid upon the dissolving plate, decreases its solvent power for cyanide of silver, makes its particles less mobile, and causes it to act in some degree upon base metals, and thus endangers the adhesion of the deposits upon them. Some electro-platers think the presence of these salts not injurious, but most consider them highly detrimental.

137. *Solution by Battery Process.*—The same silver solution may be formed by the battery process (89) as well as by the chemical method, and this process has its own advantages and disadvantages; it is very convenient in making a small quantity of liquid, because it enables the operator to make it quickly, to avoid the trouble of making the nitrate solution, of precipitation, of washing, and of the attendant risk of loss of materials; but it has the disadvantage of converting a large proportion of the cyanide of potassium into caustic potash, by taking its cyanogen to form cyanide of silver, and setting the potassium free, which immediately combines with the oxygen of the water, forming caustic potash, which dissolves in the liquid; whilst the hydrogen of the water is evolved at the cathode, and the dissolved potash gradually becomes converted into carbonate of potash by absorption of carbonic acid from the atmosphere. Neither caustic potash nor carbonate of potash are so injurious in the liquid as chloride of potassium; still they diminish the action of the liquid upon the dissolving plate, render it a worse conductor, reduce its solvent power for cyanide of silver, and make its particles less mobile.

138. *Solid Deposition of Silver.*—Mr. Alexander Parkes took out a patent, March 29, 1841, for improvements in the solid deposition of silver. He converts an ounce of silver into oxide of silver, by first dissolving it in nitric acid, and then precipitating it by caustic potash; he then dissolves the oxide together with sixteen ounces of cyanide of potassium in two gallons of water, and uses the resulting liquid for depositing solid articles in silver.

139. Mr. Edmund Tuck took out a patent, June 4, 1842, for "improvements in depositing silver upon german silver." For plating the commoner qualities of this alloy he uses a solution composed of sulphate of silver dissolved in a solution of carbonate of ammonia, and for the best quality he uses cyanide of silver dissolved in a solution of carbonate of ammonia. The solutions are formed by dissolving 70 parts of carbonate of ammonia in distilled water, then adding 156 parts of sulphate of silver, or 134 parts of cyanide of silver, and boiling the liquid until the salt is dissolved; for coating common german silver he adds half an ounce of sulphate of silver to 107 grains of bicarbonate of ammonia.

140. For depositing purposes, a solution composed of water 20 parts, cyanide of potassium four parts, and acetate of silver one part, conducts very freely, and yields a fine white deposit of silver. A solution composed of water 25 parts, prussic acid 65 parts, "black" cyanide of potassium 12 parts, and cyanide of silver 10 parts, is also a very good one.

141. Many electro-platers use a cyanide solution containing about half an ounce of silver to the gallon, and add a very large proportion of free cyanide to make it conduct freely; such a solution has the advantage of being comparatively inexpensive in its first formation, quick in working, and yields metal of an average character; but it is rather difficult to manage in hot weather, and dissolves the anode very rapidly, on account of the large proportion of free cyanide. In practice, the amount of silver to the gallon varies from half an ounce to about four ounces, but ordinary solutions contain about one or two ounces to the gallon; the amount of *free* cyanide of potassium also varies from about half the weight of the silver dissolved in the liquid to five or ten times this quantity; a very good proportion is about three-fourths of the weight of the dissolved silver; but there is no rule generally recognised in the trade upon this point; some manufactures use a very large and others a very small proportion.

142. A good plating liquid should contain one equivalent (65 parts) of pure cyanide of potassium, and one equivalent (134 parts) of cyanide of silver, besides *free* cyanide, and sufficient water to form a thin liquid. It is necessary to have *free* cyanide, because in working the solution insoluble cyanide of silver is formed and requires *free* cyanide of potassium to combine with it and form the soluble double cyanide, at the same time cyanogen and cyanide of potassium are set free at the cathode or receiving surface by the deposition of the silver; and as it requires some time for those substances to mix with the liquid and reach the dissolving plate, *free* cyanide must be provided. The necessity of having sufficient water to form a *thin* liquid arises from the double cyanide formed at the dissolving plate, being specifically heavier than the liquid, having a tendency to sink to the bottom, whilst the cyanogen and cyanide of potassium set free at the surface of the articles, being specifically lighter, tends to rise to the surface; at the same time each of them mixes more or less with the surrounding liquid by capillary attraction or adhesion, and the more dilute the liquid is, the more mobile are its particles, and the more rapidly does this mixture take place. This explains why strong silver solutions require more frequent stirring than weak ones to keep them uniform. In some manufactories, where they have steam-power at command, the articles are kept in constant motion by machinery swinging them gently to and fro; but in ordinary electro-plating establishments, the silver solutions are stirred every evening.

143. If a solution contains but little water and a large supply of free cyanide, and from any cause the battery current becomes suddenly weak towards the evening, the silver deposited upon the articles will be re-dissolved, in consequence of the liquid about the dissolving sheets having by the day's work become saturated with silver, and that about the articles become full of free cyanide; the two electrodes (*i.e.*, the dissolving plates and the articles) form a kind of voltaic battery (one metal in two liquids), which develops a current of electricity in an opposite direction to the original one, and thus re-dissolves the deposited silver.

144. *Bright Silver Solution.*—Much practical interest was for a long time attached to the anticipated discovery of a solution by which silver might be deposited in a *bright* condition, and the labour of burnishing be thereby avoided or lessened; and

this discovery was at last effected as follows:—Some operators at the electro-plate works of Messrs. Elkington and Mason, Birmingham, were engaged in some experiments on moulds containing bisulphide of carbon; whilst these moulds were being coated with silver in the depositing vats, the depositor observed some very peculiar appearances upon the various articles receiving a deposit in the vat, some having very bright patches upon them like burnished metal. From the known presence of bisulphide of carbon, experiments were tried of adding that substance to a quantity of silvering liquid, which ultimately resulted in success, and a patent was taken out by Messrs. Lyons and Millward, March 23, 1847, in which they give the following instructions for forming a "bright solution:"—"Add to the usual solution of silver in cyanide of potassium, bisulphide of carbon, terchloride or other chloride of carbon, sesquichloride of sulphur, or hyposulphite of either potash or soda. The bisulphide of carbon may be used alone or dissolved in sulphuric ether; or it may be used in conjunction with any of the other substances mentioned above, but the patentees prefer using it as follows:—Six ounces of bisulphide of carbon are put into a stoppered bottle, and one gallon of the usual plating liquid added to it, the mixture is then shaken and set aside for twenty-four hours; two ounces of the resulting solution are then added to every twenty gallons of the ordinary plating solution in the vat, and the whole stirred together; this proportion must be added every day, on account of the loss by evaporation, but when the mixture has been made several days, less than this proportion may be used at a time; when hydrocarbons are used instead of the bisulphide, a much larger quantity must be added. This proportion gives a bright deposit, but by adding a larger proportion a dead surface may be obtained, very different to the ordinary dead surface." This substance is generally employed throughout the trade, although few are licensed to use it. Other compounds are also used, but to a very limited extent; among these are sulphur and collodion. A solution of iodine and gutta-percha in chloroform is said to be more permanent in its effect than the bisulphide of carbon. The liquid is generally added to the vat in the evening after the work has been taken out. A method of bright *gilding* has also been recently brought into use in the trade.

145. *Method of Making Cyanide of Potassium.*—As nearly all the solutions which are used for electro-silvering and gilding contain cyanide of potassium, and as this substance is used extensively in electro-deposition generally, it will be necessary for the practical depositor to understand how it is made, and to possess information respecting its impurities, and the method of testing its quality. It is nearly always made by the following process:—Take ferrocyanide of potassium (yellow prussiate of potash), pound it fine, and gently heat it in an iron pan, with constant stirring until quite dry; treat a quantity of the best quality of carbonate of potash in a similar manner. When they are perfectly dry, add about three parts of the carbonate to eight parts of the ferrocyanide, and thoroughly mix them; heat the mixture rapidly in an iron ladle or crucible, until it melts into a clear liquid, when gas will be evolved from its surface. It should be maintained at a moderate or dull red heat about fifteen or twenty minutes, or until the end of a cold iron rod dipped into it shows a white sample. The fusion should not be continued until the evolution of gas ceases, or the product will be of a gray colour. It should be kept covered as much as possible. By allowing it to stand undisturbed a few minutes at the latter part of the operation, and occasionally tapping the sides of the ladle or crucible, the iron of the ferrocyanide will settle at the bottom as a fine black powder; the

colourless cyanide of potassium may then be poured off into a cold iron pan, or upon a thick and cold iron plate; it should be broken up whilst still warm, and preserved in a well-stopped jar.

The black sediment, which contains much cyanide of potassium, should be scraped out of the vessel while still hot, and preserved, as water will at any time dissolve the cyanide. If the process has been well conducted, the product will be of a clear white colour, or at most but very slightly gray. A larger proportion of cyanide of potassium is obtained by this process than when ferrocyanide alone is employed, because in the former case one-third of the cyanogen (that which was combined with the iron) combines with the potassium of the carbonate of potash, whilst in the latter case it is lost; the cyanide produced by the fusion of the ferrocyanide of potassium alone is of a grayish-black colour, and is termed "black cyanide."

146. *Cyanide of Potassium.*—Commercial cyanide of potassium varies very much in price; the best quality of white cyanide is sold retail from 2s. 3d. to 2s. 6d. per pound in the United States of America; in England it varies from 2s. 6d. to 4s. 6d. per pound, according to quality; and black cyanide may be obtained retail at 3s. 10d. per pound. By dissolving several specimens of commercial black cyanide in water, and filtering the solution, we found the proportion of black impurity in them varied from one-fourth to one-sixth of their weight; and by experiments with the commercial white cyanide we found that one part (200 grains) of it, dissolved in about one and a quarter parts (230 grains) of distilled water at 60° Fah., and that it dissolved much more freely in water containing hydrocyanic acid.

147. *Impurities in Cyanide of Potassium.*—According to the researches of Messrs. Glassford and Napier ("Philosophical Magazine," 1844), commercial white cyanide generally contains about thirty-five per cent. of impurities, and often as much as fifty per cent., in the form of carbonate and sulphate of potash, chloride of potassium, cyanate of potash, ferrocyanide of potassium, and silica; and if the mixture of salts from which it is made is not dry, ammoniacal compounds are also formed. The sulphate of potash and chloride of potassium occur in the commercial carbonate of potash; the silica is present when we operate with an earthen crucible; and even when the process is well conducted and pure materials used, the product contains twenty per cent. of cyanate of potash, produced partly by the contact of the air with the melted mixture.

148. *Testing Cyanide of Potassium.*—According to the same experimentalists, the quantity of pure cyanide in any given sample of cyanide of potassium may be correctly ascertained thus:—Make two solutions, one of the given cyanide and one of nitrate of silver, each containing known weights of the salts, say one ounce of the cyanide dissolved in six ounces of distilled water in a graduated glass vessel, and 175 grains of the crystallized nitrate dissolved in about two or three ounces of distilled water; add the cyanide solution carefully and slowly to the nitrate of silver liquid, until the precipitate first formed is all re-dissolved. The quantity of the cyanide solution required to effect this (with the above quantity of nitrate of silver) will have contained 130 grains of pure cyanide, and from the quantity used we may easily calculate the amount of pure cyanide in the whole ounce. It is said, that "when nitrate of silver is added to a solution of cyanide of potassium, so long as the precipitate formed is all re-dissolved, we obtain the *whole* of the cyanide of potassium in combination with the silver; none of the other salts in solution take any part in the action, even though they be present in a large proportion. This enables us to test the exact quantity of cyanide of potassium in any sample."

149. *Chemical Characters of Cyanide of Silver.*—In the presence of cyanide of potassium, as we are informed by Messrs. Glassford and Napier, cyanogen has a greater affinity for silver than anything else has, decomposing every salt of silver except the sulphide, and forming cyanide of silver. In dissolving the oxide, carbonate, chloride, or ferrocyanide of silver, in a solution of cyanide of potassium, they are all decomposed, and cyanide of silver always formed. Cyanide of silver should be dried below 260° Fah.; hydrochloric acid decomposes it with a solution of hydrocyanic acid gas; cold nitric acid has no action upon it; a boiling mixture of sulphuric acid and water decomposes it, with escape of hydrocyanic acid gas, and formation of sulphate of silver; it is soluble in the alkaline chlorides, but its best solvent is an aqueous solution of cyanide of potassium, of which it requires one equivalent (65 parts) to dissolve one equivalent (134 parts). The resulting solution, when evaporated, yields crystals of double cyanide of silver and potassium, which are soluble in eight parts of cold and in one part of boiling water. The solution of this double salt, which is nearly the same as the ordinary plating solution, may be boiled for any length of time without being decomposed, and it is very little affected by light; it is decomposed by all acids, and they precipitate the silver as cyanide of silver; the hydro-acids—hydrochloric acid, for example—decompose the cyanide of silver also; sulphuretted hydrogen precipitates the silver as sulphide of silver.

150. **Gold Solution.**—Various salts of gold have been used for electro-deposition, among which are the hyposulphite, sulphite, iodide, bromide, terchloride, cyanide, and sulphocyanide. Finely-divided gold, which is sometimes used for dissolving, may be obtained by adding a solution of protosulphate of iron to a solution of terchloride of gold, as long as a greenish-brown precipitate occurs; this is gold in a state of very minute division. Oxide of gold is obtained by adding to a solution of terchloride of gold a cold solution of caustic potash, until it ceases to produce a precipitate; or by digesting terchloride of gold with magnesia; washing the latter precipitate, first with dilute nitric acid, and then with water only. Iodide of gold is formed, either by digesting oxide of gold in hydriodic acid, or by adding a solution of iodide of potassium to a solution of terchloride of gold as long as a precipitate is produced, washing the precipitate with water; it is of a yellow colour, insoluble in cold water, but freely soluble in a solution of iodide of potassium. Bromide of gold may be formed either by digesting finely-divided gold, or oxide of gold, in liquid bromine contained in a stoppered bottle. It is a salt of a rich red colour, and is soluble in water.

151. *Chloride of Gold.*—Terchloride of gold, commonly known as chloride of gold, is the most usual salt of the metal, and its preparation requires separate explanation. It is formed as follows:—Take a mixture of either two or three measures of hydrochloric acid, and one measure of nitric acid; make the mixture hot, and add pure grain gold to it as long as it will dissolve; it evolves gas whilst dissolving. When it is all dissolved, slowly evaporate the liquid until it crystallizes to a dark ruby red mass, or it may be of a yellow colour, according to the proportions of the ingredients. This is terchloride of gold, and contains one equivalent (197 parts) of gold, and three equivalents (106·5 parts) of chlorine; if it is too much evaporated, chlorine gas will be evolved, the gold will be set free and be mixed with the salt, and will precipitate on dissolving the salt in water. To produce the *yellow* chloride, mix together, in a glass or stoneware vessel, one part by weight of nitric acid, three parts of hydrochloric acid, one part of fine gold, and one part of water; cover the vessel with a glass dish, make the liquid quite hot, and maintain the heat until the red vapours cease; if some of the gold remain undissolved, add more

of the liquid mixture, and treat as before; when the vapours cease, remove the glass cover, and replace it by folds of blotting-paper, and evaporate until it crystallizes *on cooling* into yellow chloride of gold. The red chloride is formed in the same manner, except that the liquid mixture should be composed of one part of nitric, and two parts of hydrochloric acid, more being added than is necessary to dissolve all the gold. One ounce of gold will dissolve in about four ounces of the mixture, and when crystallized into the red mass, will weigh about one ounce and 165 grains.

152. *Cyanide of Gold.*—"Cyanide of gold is formed by cautiously adding a solution of cyanide of potassium in six parts of water, to a normal solution (*i.e.*, not containing any *free* acids) of terchloride of gold, consisting of one part of the chloride and five parts of water, until a copious yellow precipitate settles down; if more cyanide of potassium is added, the precipitate becomes dirty yellow, and is more quickly deposited; a still larger quantity renders it orange yellow. It is a crystalline powder, permanent in the air. By ignition it is resolved into gold and cyanogen gas; it is not decomposed by sulphuric, hydrochloric, or nitric acid, nor by aqua regia, unless freshly precipitated, and then only slowly. It is not decomposed by sulphuretted hydrogen; hydrosulphate of ammonia dissolves it slowly but completely, forming a colourless solution, from which, by the addition of acids, sulphide of gold is precipitated. It dissolves in aqueous solutions of ammonia, hyposulphite of soda, or alkaline cyanides; but not in water, alcohol, or ether."

153. "Gold precipitated from a solution of chloride of gold by protosulphate of iron, dissolves in a boiling solution of cyanide of potassium; a hot solution of cyanide of potassium will also dissolve ordinary metallic gold if air be present. Both oxide of gold and aurate of ammonia, dissolve completely in a solution of cyanide of potassium, and form double cyanide of gold and potassium. Cyanide of gold requires 23 parts of cyanide of potassium dissolved in water to dissolve it. For every one part of gold to be dissolved by the battery process, six parts of cyanide of potassium dissolved in from two to four times their quantity of water, at 100° Fah., is required; two electrodes of gold being connected with a suitable battery, and immersed in it until the required quantity of gold is dissolved."—"The crystallized cyanide of gold and potassium dissolves in seven parts of cold, and in half a part of hot water (Himly); in four parts of cold and in 0·8 parts of hot water (Glassford and Napier). It dissolves very sparingly in alcohol. Its aqueous solution gilds copper and silver by simple immersion, especially if hot, and the copper and silver dissolves in it."

154. *Gilding by Immersion.*—The following solutions have been used for gilding by the simple immersion, or "water-gilding" process:—First, dissolve five troy ounces of grain gold in fifty-two avoirdupois ounces of hot aqua regia, until vapours cease to be evolved. Decant the clear liquid when cool, dilute it with four gallons of distilled water, add twenty pounds of purified bicarbonate of potash, and boil it for two hours. The articles to be gilt are immersed in the liquid from a few seconds to one minute, according to the kind of metal immersed, and the temperature and newness of the liquid; warmth assisting the action, and a new liquid acting more quickly than an old one. Second, for gilding silver articles, dissolve equal parts of bichloride of mercury (corrosive sublimate) and sal-ammoniac in nitric acid; add pure gold to it, and evaporate the liquid by heat to half its volume. Apply the liquid while hot to the surface of the article.

155. Joseph Steele's patent, dated August 9, 1855.—Dissolve an ounce of gold in a mixture of four ounces of hydrochloric acid and eight ounces of nitric acid, and evaporate the solution to dryness. Fuse together 24 ounces of ferrocyanide of potassium,

and 12 ounces of carbonate of potash; when it is nearly cold, dissolve it in two or three gallons of pure boiling water, cool and filter the solution, then add the chloride of gold, and boil it for a quarter of an hour. The articles to be coated are connected with a piece of zinc, of suitable size, and immersed in the liquid, the latter being at a temperature of 80° or 85° Fah.

156. *Gold Solution for the Battery Process.*—For the battery process there are many gold solutions, though but few good ones:—1st, The hyposulphite of gold and soda, which is formed by dissolving chloride of gold in a solution of hyposulphite of soda; it is not considered a good liquid for practical purposes. 2nd, The sulphite of gold and potash, used by Mr. Woolrich; his solution was made by adding sulphite of potash to water, saturating five-sixths of the resulting liquid with oxide of gold, and then adding the other portion of solution to form *free* sulphite. 3rd, The terchloride of gold dissolved in water; it is a very inferior liquid for practical purposes, because all the common metals decompose it. 4th, The bromide of gold, proposed by Mr. Spencer; his solution was made as follows:—"Make a mixture of equal parts of bromine and alcohol, and of this mixture take one part, of acetic acid one part, and four parts of water containing a few drops of sulphuric acid." The resulting liquid is then nearly saturated with gold by suspending it in two electrodes of gold, and connecting them a sufficient time with a suitable battery; when nearly saturated, add to the solution three times its volume of water containing a few drops of sulphuric acid.

157. *Electro-Gilding Liquid.*—The best liquid that has yet been tried for practical electro-gilding, consists of the double cyanide of gold and potassium dissolved in water. It was first patented by Messrs. Elkington, and may be formed, either by dissolving finely-divided gold, or any salt of gold, in a solution of cyanide of potassium; or by the battery process, by suspending two electrodes of gold in a solution of cyanide of potassium, and passing a current from a small battery until the cathode receives a proper deposit, the liquid being at about 100° or 150° Fah.

158. *Cyanide of Gold by Chemical Process.*—The cyanide of gold and potassium gilding solution is often made by the chemical method, as follows:—Form some terchloride of gold (151), and dissolve it in water; then either add a cold solution of caustic potash as long as a precipitate is produced, filtering and washing the precipitate with distilled water; or by digesting the chloride solution with magnesia; filter, and wash the precipitate first with nitric acid and then with distilled water; or add to the chloride liquid a solution of carbonate of ammonia, until a precipitate ceases to be formed; filter, and wash the precipitate with water. The precipitates produced by potash or by magnesia, consist of oxide of gold; whilst those produced by ammonia, or its carbonate, are aurate of ammonia (fulminate of gold), a very explosive compound. The precipitate, after being well washed by the successive additions of clean water, should be added, whilst still wet, to a solution of cyanide of potassium, containing the proportion of one pound of cyanide to one gallon of water, and then about one-fifth more of the same solution should be added to form *free* cyanide. A very good proportion of the ingredients is, one ounce of gold, one pound of cyanide of potassium, and one gallon of water. The wash-waters should not be thrown away without first being tested for gold, by immersing a piece of bright zinc in them, and observing if it receives a yellow deposit; if it does, a solution of protosulphate of iron should be added as long as a precipitate of a greenish-brown powder, which is metallic gold, is produced. If this fails to precipitate the whole of the

gold, a sheet of bright zinc should be immersed in the liquid, taken out occasionally, and the deposit of gold brushed off by a hard brush in water containing a little sulphuric acid. The greater the quantity of *free* acid contained in the original chloride solution, and the larger the excess of potash, ammonia, or carbonate of ammonia added, the greater is the amount of gold dissolved in the wash-waters. If, when we dissolve the terchloride of gold in water, a yellow powder remains undissolved at the bottom of the vessel, it indicates that there is no free acid in the salt, and may be redissolved by the addition of a small quantity of the mixture of nitric and hydrochloric acids and the application of heat.

159. *Solution by Battery Process.*—The same solution may be made by the battery process, thus :—Dissolve some cyanide of potassium in hot distilled water, in the proportion of from one to two pounds to the gallon; nearly fill a small porous cell with the liquid, and immerse it nearly to its edge in the solution; place a large gold anode in the outer liquid and a small bright copper cathode in the liquid of the porous cell, and connect them with about three pairs of Smee's batteries—the gold anode with the platinised silver by one wire, and the copper cathode with the zinc by another wire, allowing the current to pass, until, by transferring the cathode for a short time to the outer liquid, it receives a good deposit of gold, the solution being maintained at a temperature of about 150° Fah.; the liquid of the porous cell should then be transferred to the outer solution and the process stopped. The amount of gold dissolved is not of material consequence provided the deposit is good, as a solution may contain from half an ounce to four ounces to the gallon and be a good depositing liquid.

160. *Gilding Solution of M. Ruolz.*—"Dissolve ten parts of cyanide of potassium in 100 parts of distilled water; filter it, and add one part of cyanide of gold, prepared with care, well washed, and dried out of the influence of light; keep the mixture in a closed glass vessel, at the temperature of 60° to 77° Fah. for two or three days, out of the presence of light, with frequent stirring."

161. *M. Becquerell's Gilding Liquid.*—"Dissolve one part of terchloride of gold and ten parts of ferrocyanide of potassium in one hundred parts of water; filter the liquid, to remove the separated cyanide of iron; add 100 parts of a saturated solution of ferrocyanide of potassium, and dilute the mixture with once or twice its volume of water. In general the tone of the gilding varies according as the solution is more or less dilute; the colour is most beautiful when the liquid is most dilute, and most free from iron. To make the surface appear bright it is sufficient to wash the article in water, acidulated with sulphuric acid, rubbing it gently with a piece of linen cloth."

162. *Gilding Liquids of M. Fizeau.*—"1st, Dissolve one part of dry chloride of gold, in 160 parts of distilled water; then add, little by little, a solution of carbonate of potash in distilled water until the liquid begins to become cloudy; we may use this liquid immediately. And, 2nd, used by M. Lerebour :—Dissolve one gramme of chloride of gold and four grammes of hyposulphite of soda in one litre of distilled water."

163. *M. Levol's Solution for Gilding Silver.*—"Dissolve neutral chloride of gold, then add an aqueous solution of sulphocyanide of potassium, until the precipitate first formed is redissolved. The liquid will retain a slightly acid reaction; if it has lost it, it must be renewed by adding a few drops of hydrochloric acid."

164. *By M. De Briant.*—"Dissolve thirty-four grammes of gold in aqua regia, and evaporate the solution until it becomes neutral chloride of gold; then dissolve the chloride in four kilogrammes of warm water, and add to it 200 grammes of commercial magnesia, carefully sifted. The gold is precipitated in union with the magnesia; filter

and wash with pure water; digest the precipitate in forty parts of water mixed with three parts of nitric acid to remove the magnesia; then wash the oxide of gold remaining with water, until the wash-water exhibits no acid reaction. Next dissolve 400 grammes of ferrocyanide of potassium, and 100 grammes of caustic potash, in four litres of water, add the oxide of gold, and boil the solution about twenty minutes. When the gold is dissolved there remains a small amount of iron precipitated, which may be removed by filtration, and the liquid, of a fine gold-yellow colour, is ready for use. It may be used either hot or cold."

165. *Formulas of M. J. L.*—"1st, Take thirty-one grammes and twenty-five centigrammes of oxide of gold, five hectogrammes of cyanide of potassium, and four litres of water, and boil them together half an hour. The resulting solution must be worked hot, and may be used to gild copper, brass, and silver. 2nd, Dissolve ten parts of ferrocyanide of potassium and one part of dry terchloride of gold in 100 parts af water; oxide of iron will be precipitated. Boil the solution two or three hours, in a porcelain or glass vessel, until a precipitate collects at the bottom and the supernatant liquid is transparent and of a canary-yellow colour; filter the solution, and dilute it with three times its volume of water."

166. A process or branch of trade termed "solid depositing" has of late years been gradually extending itself. It consists in making solid articles of gold and silver, by electro-deposition, upon gutta-percha or other moulds—such, for instance, as watch and clock faces, ornamental snuff-boxes, and other articles elaborately chased or engraved, or which have very complex or undercut ornaments upon them; the expense of multiplying these by the electro-process being less than by the ordinary means. Mr. Alexander Parkes took out a patent, dated March, 1841, for a solution for depositing solid articles in gold; it is formed thus:—Dissolve one ounce of pure gold in aqua regia, and evaporate the solution to dryness; then add two gallons of water and sixteen ounces of cyanide of potassium, and work the resulting liquid at a temperature of about 120° or 130° Fah.

167. *Salts of Platinum.*—The only common salt of platinum is the bichloride; it is formed by adding pieces of platinum-foil to hot aqua regia as long as gas is evolved from them; the solution, which is then of a deep red colour, should be evaporated nearly to dryness and left to cool.

168. *Platinum Solutions.*—For platinizing silver by simple immersion process, we may use a solution consisting of bichloride of platinum, dissolved in water containing one-fourth its volume of nitric acid, or we may use simply a very hot aqueous solution of the bichloride alone. Nearly all metals decompose the bichloride solution, and become coated with platinum in it by simple immersion. For the battery process we may use solutions of the iodide, bromide or bichloride, or the double chloride of platinum and sodium. The solution of the double chloride of platinum and sodium is made by dissolving one equivalent (169·7 parts) of bichloride of platinum and one equivalent (58·5 parts) of common salt, in water; it requires a small anode of platinum and a very weak battery to obtain a reguline deposit. A good solution for depositing reguline platinum may also be made by dissolving bichloride of platinum and common salt in a solution of caustic potash.

169. *Palladium Solutions.*—A solution of double cyanide of palladium and potassium may be used for depositing palladium. It may be made by chemical means, by dissolving palladium in nitric acid, precipitating the solution by a solution of cyanide of potassium, washing the precipitate, and dissolving it in a solution of cyanide of

potassium to saturation, and then adding a little free cyanide; or it may be easily made by the battery process, by passing a current through a large palladium anode in a solution of cyanide of potassium, until a clean smooth cathode receives a good deposit. This is an excellent solution for depositing reguline metal; it acts upon the anode with uncommon energy, conducts freely, and deposits plenty of reguline metal by easy management; a thin deposit of palladium obtained in this solution has been used for fixing Daguerreotype pictures, instead of gold, and is said to give them a finer tone.

170. *Selected Practical Liquids.*—Having enumerated nearly all the solutions which have been used for depositing different metals, and described the modes of forming them, we now offer a selection of those which are in most general use in the trade:—

1st. For depositing zinc, which is not very often attempted, the sulphate solution (105) may be used.

2nd. For depositing copper upon all ordinary metals except zinc, tin, lead, iron, and steel, and upon gutta-percha, wax, and elastic moulds, after being made conductible by the battery process, the sulphate solution (120), is in general use; but for surfaces of tin, lead, iron, or steel, the solution of cyanide of copper and cyanide of potassium (120) is used.

3rd. For the deposition of brass upon all ordinary metals, the patented solution of Messrs. Morriss and Johnson (127) is very successfully used; the solutions of Brunel (126) and Salzede (125) are also in practical use; and, in the United States of America, a solution very similar to that of Messrs. Morriss and Co. is in use.

4th. For depositing silver upon all common metals, the solution of double cyanide of silver and potassium (135), is almost universally used; the only exception is where the double sulphite of silver and potash is used, but only to a small extent, the magneto-machine being in some cases used with it.

5th. For gilding all ordinary metals, almost the only liquid used is the double cyanide of gold and potassium (157 and 158), the only exceptions being a few minor modifications of it in private use.

6th. For platinizing, the only solution in practical use is the bichloride (167).

7th. For *solid* deposition of silver and gold, the patented solutions of Mr. Alexander Parkes (138 and 166), may be used.

171. **Preparing Metal for Receiving a Deposit.**—The electro-depositor having acquired a general knowledge of depositing liquids, as well as of the necessary manipulation, and having made the several solutions necessary for his ordinary use, will require to prepare his articles for receiving a deposit. All metallic articles require to be cleaned and otherwise prepared before they are fit to receive a deposit; this preparation differs of course according to the nature of the article, whether the deposit is required to adhere firmly to the surface, or is merely used as a matrix, from which the deposited metal is to be removed.

172. *Cast Iron and Zinc.*—Articles formed of zinc, wrought iron, cast iron, or steel, are first immersed a few minutes in a boiling solution of caustic potash to remove any grease, tar, or oily substance which may be upon them; they are then washed in water, and those of wrought or cast iron are immersed in "pickling liquid" (82), until the acid acts rather freely upon them; rough cast iron requires a stronger liquid than smooth wrought iron; after being again washed in water, they are "scratched" at the brush (80), and if they are very coarse castings or rusty articles, they may require several soakings in the dilute acid, and scourings with sand and a hard brush, and even filing to make them quite clean.

173. *Copper, Brass, and German Silver.*—Those formed of copper, brass, or german silver, should be boiled in the potash liquid, washed in water, dipped into nitric acid or into "dipping liquid" (82), and then washed in water, and dipped into a solution of nitrate or cyanide of mercury (84), before immersing them in the silvering solution.

174. Sometimes, in order to assist in cleaning the articles, they are suspended for a short time in the depositing liquid, in contact with the negative pole of the battery; this dissolves the surface, and loosens their impurities, unless they are very foul, or the solution is too valuable. In every case they should be well rinsed with water to remove the adhering acid, before dipping them into the mercury solution, or immersing them in the depositing vat. All objects which are to have a definite weight of metal deposited upon them, are weighed, and their weight noted down after they have been cleaned.

175. *Wiring Articles.*—The articles, having been cleaned throroughly, have wires of copper attached to them, to suspend them by when in the vat. The wires differ in size with different articles; with small ones, such as spoons, knives, forks, snuffers, teapots, jugs, and such articles, size No. 20 or 22 of the Birmingham brass wire guage, and about eighteen or twenty inches long, are used. Very large articles, such as fire-irons, fenders, hat-stands, and articles of ornamental iron-work, are suspended in the solution by strong copper or brass hooks; in some cases where a powerful and certain connection is required, the wires are soldered to the articles.

176. *Preparing Articles for Adhesive Deposits.*—We have already explained how necessary it is that all articles intended for the depositing vat should be cleaned in the most perfect manner possible, before being immersed in the depositing liquid, otherwise the deposit will not adhere. Articles of copper, brass, or german silver, which are to be silver-plated, should also be dipped into one of the solutions of mercury (84); otherwise the deposit will either not adhere at all, or will vary in appearance in different parts; and in consequence of this perfect degree of cleanliness required, the cleaning of them often involves more trouble than the depositing. All articles should be plunged while still wet from the cleaning process, into the depositing vat. The practical minutiæ of preparing the surfaces of different metals for receiving adhesive deposits of other metals, varies in almost every manufactory, and much information yet remains to be developed upon this point; for want of this knowledge, the most skillful operators sometimes fail in producing perfect adhesion, especially upon zinc, cast iron, steel, and Britannia metal.

177. *Preparing Metals for Non-adhesive Deposits.*—Metal articles which are to receive non-adhesive deposits, such as medallions, of which copies are desired in copper, should be allowed to remain a sufficient time to slightly oxidate after being cleaned, before being plunged in the depositing vat, the oxide preventing adhesion. In some cases they are rubbed over with cotton wool slightly moistened with a very weak solution of bee's-wax dissolved in camphine in the proportion of a piece of wax of the size of a small pea in a quarter of a pint of the spirit; others use a little sweet oil, which is immediately wiped off with a fresh piece of dry cotton wool.

178. "*Stopping-off*" *to Prevent Deposition.*—Many articles which are to receive deposits require to have portions of their surface "stopped-off," to prevent the deposit spreading over those parts; for instance, in taking a copy of one side of a metal medallion, the opposite side must be coated with some kind of varnish, wax, or fat to prevent deposition; or in gilding the inside of a cream jug which has been silvered on the outside, varnish must be applied all round the edge on the outside for the

same reason. For gilding and other hot solutions, copal varnish is generally used; but for cold liquids and common work, an ordinary varnish, such as engravers use for a similar purpose, will do very well. In the absence of other substances a coating of sealing-wax dissolved in naphtha will answer every purpose.

179. **Moulding and Copying Works of Art.**—The electro-depositor who includes in his business the multiplication of works of art, as well as the simple plating of metal articles, will require a knowledge of the art of moulding. To copy both sides of a metallic coin or medal in the mixture of gutta-percha and marine glue recommended (85), take a strip of thin sheet copper, brass, or tinned iron about an inch wide, wind it closely round the edge of the medal, and solder its ends together; wipe the medal and take two balls of the composition, quite hot and soft, and press them simultaneously against the two faces of the medal, working the material from the centre towards the circumference to exclude bubbles of air; place two thick plates of cold metal, one on each side, and gradually screw up the whole in a vice, or screw press, gently at first, but increasing the pressure to a high degree as the materials become hard. When it is quite cold, which will be in about two hours, the two copies may be easily removed from the original, by inserting the end of a gimlet in their backs, and drawing them out; they are easily removed, because the composition slightly contracts in cooling. They will present fine impressions of the original, and be perfectly free from air bubbles, if the operation has been carefully performed.

180. *Elastic Moulding.*—If the medallion is undercut, it must be copied in "elastic moulding" (86), thus:—Encircle its edge by a strip of stout paper, and pour the mixture upon its surface quite hot, and of the consistency of treacle, to the depth of half an inch or more, according to the size of the medal and the depth of its hollow parts, brushing its surface beneath the liquid with a brush having fine and long hairs, to remove air bubbles. Allow the mixture to remain until it is quite firm, which will be from two to twenty-four hours, according to its bulk; take off the paper, and remove the mould very gently, carefully stretching and drawing it at the same time in the direction of the overhanging parts, to prevent injury. Should the object to be copied be a hollow metallic bust, proceed as follows:—Partly fill it with sand, to make it heavy and thus prevent its rising in the liquid, and cover its opening by sticking a piece of millboard strongly over it; then place the bust in the centre of a cylindrical and taper vessel, a few inches deeper and wider than itself, and pour the melted composition in steadily, until it is a few inches above the top of the head, tapping the bust, and inclining the outer vessel, to facilitate the escape of air bubbles. When the composition is quite firm, which it will be in about twenty hours, it may easily be removed from the vessel by shaking, if the vessel has been previously well oiled; the mould may then be removed from the bust by previously marking on its lower end the position of the face, passing a knife carefully up the back of the bust nearly to the crown of the head, and opening the elastic mould with your hands, whilst a second person lifts out the bust. If the original bust is composed of plaster, it must be previously saturated with oil to prevent the melted composition adhering to it.

181. **Rendering Moulds Conductible.**—To render the surfaces of non-metallic moulds conductible, there are two methods in use,—first, to cover them with a thin film of blacklead by brushing; and, second, to coat them with a minute film of gold or silver by chemical means. The first of these methods is generally used for moulds composed of gutta-percha, wax, resinous composition, or plaster saturated with

oil, where the parts are not much undercut; and the second for elastic moulds, because the blacklead cannot be readily applied to all their recesses.

182. *Blackleading.*—To apply blacklead to a small round or oval medallion formed of gutta-percha, or of gutta-percha and marine glue, first insert the sharp end of a piece of copper wire, size No. 16 or 18, and about fifteen or twenty inches long, into the edge of the mould near its face, then pass a piece of fine copper wire, size No. 28 or 30, once tightly round the edge of the mould close to its face, securing its ends to the other wire. Fix a strip of paper about one inch wide, by means of sealing-wax, tightly round the edge, to prevent the blacklead passing anywhere except upon the face of the mould. Apply the blacklead by a soft camel's-hair brush with a large and thick body of short hairs, breathing upon the face of the mould occasionally to facilitate the adhesion of the blacklead; and when the medal is perfectly black and bright, blow off the superfluous blacklead, and remove the paper; it is then ready for receiving a deposit, the whole operation occupying about ten or fifteen minutes with a small object the first time of preparing it, but less in subsequent operations. If the mould is very large, and especially if it has deep hollows in its surface, it will require, after being blackleaded, to have several short and fine copper "guiding wires" carefully attached to the main wire, and their free ends slightly inserted in the face of the mould in the most hollow and distant parts, or to lie in contact with them, in order to cause the deposit to commence and spread there as well as round the edge. If this precaution is not taken, the deposit will be much thinner over those parts, than upon the nearer and more prominent places, and sometimes will not spread over them at all.

183. *Preparing the Surfaces of Elastic Moulds.*—Elastic moulds are treated in a different manner. First, a stout connecting wire is attached, then a number of fine copper "guiding-wires" are twisted round it, and their free ends slightly inserted in the face of the mould in all the hollow and distant parts; the mould is then either dipped into the phosphorous solution (87), or its surface is covered with that liquid; and, after it has been drained clean, it is allowed to remain until perfectly dry; the silver solution is next applied to it (87), in like manner, for several minutes, until it appears black, with a metallic lustre like black china; it is then gently rinsed with distilled water, and the gold solution applied in the same way (87), which gives it a yellowish aspect; after another rinsing in distilled water, it is ready for receiving a deposit.

184. *Moulding by Phosphorus Composition.*—Some objects which are not much undercut, are moulded in the phosphorus moulding composition (87); and, in some cases, where they are undercut, as well as busts, they are first copied in the elastic moulding, and then the elastic mould copied in this material, the composition being but barely melted that it may not dissolve the elastic moulding. In either of these cases, instead of immersing the mould into the phosphorus, silver, and gold solutions, it is only immersed in the two latter, in the manner already described, the phosphorus contained in the mould itself serving to reduce the silver and gold.

185. *Preparing Surfaces of Glass for Deposition.*—Glass surfaces may be prepared for receiving a deposit by means of the phosphorus, silver, and gold solutions, but not very satisfactorily. A better method, which we have tried, has been silvering them by Drayton's patent process, thus:—Take one part, by weight, of liquid ammonia, three parts of alcohol, two parts of nitrate of silver, and three parts of distilled water; dissolve the silver salt in the water, add the liquid ammonia and the alcohol, shake the mixture, allow it to remain until quite clear, and pour off the clear part into the

glass vessel to be silvered, which must be perfectly clean; then add to it one quarter of a part of grape-sugar dissolved in weak spirits of wine, mix the liquid, and heat it to about 150° or 160° Fah. for about twenty or thirty minutes, and the glass vessel will become silvered; the liquid may then be removed, the vessel gently rinsed with distilled water, a connection formed by means of a fine copper wire with the film of silver and the battery, the vessel filled with a suitable depositing liquid, an anode immersed, and the surface deposited upon in the ordinary way. If the process has been successfully performed, the deposit, whether of silver or copper, spreads instantaneously over the silvered surface. The only way by which we have been able to form an adhesive deposit upon glass or porcelain, has been to send the article to a glass and porcelain gilder, and have gold-leaf burnt into their surfaces, and then depositing upon them in the usual manner.

186. *Immersion of Articles in the Vat.*—The operator having prepared the various articles and moulds, will immerse them in the depositing solution, having previously immersed the anode and completed all the connections, taking care always to connect the article to receive the deposit with the zinc of the battery, and the metal to be dissolved with the copper or silver.

187. **Regulation of Battery Power.**—In depositing all metals, it is of the greatest importance that the battery power be properly regulated, and this may be done in a variety of ways, which collectively consist, either in making alterations in the battery, in the depositing vessel, or in the wires connecting them. The *intensity* of the current is increased by increasing the number of alternations of the battery plates; by increasing the conductibility of the battery liquid or depositing solution, which may be effected either by the addition of free acid to the battery or more salt to the solution; or by increasing the thickness and decreasing the length of the connecting wires. The *quantity* of the current is increased by immersing all the battery plates deeper in their liquids, also by those means which increase the intensity. Both the intensity and the quantity may be decreased by separating the electrodes in the depositing vessel farther asunder, or by interposing a long and fine iron wire in the circuit. The most usual means adopted of increasing the *intensity* of the current is to add to the number of the batteries; and for increasing the *quantity*, to immerse all the battery plates deeper in their liquids. Sometimes, to increase the power, the temperature of the liquid may be raised, or the article placed nearer the dissolving metal; and, when a smaller quantity of current is required than the ordinary batteries can conveniently supply, a piece of sheet metal may be hung in the depositing solution with the receiving article, to receive a portion of the deposit, and thus transfer some of the power from the article to itself.

188. *Intensity and Quantity of the Current.*—The intensity of the current obtained from a series of batteries, depends upon the *number of alternations* of the metals, whilst its *quantity* depends upon the *amount of immersed surface in each alternation*, and it makes no difference whether that amount of surface is in one battery plate or in many or in one or many containing vessels. A series of similar batteries may be so connected together by wires or other conductors, as to give either an intensity or a quantity of current, provided they have screws or other conveniences for attaching the wires to the plates. For instance—1st, if we have four pairs of plates, in four separate cells, and connect them alternately, thus (Fig. 32), zinc, silver—zinc, silver—zinc, silver—zinc, silver, with wires from the terminal plates, we obtain a current possessing the intensity of four pairs, and the quantity of one; but if, 2nd, they are connected, all the zincs by one wire, and all the silvers by another wire (Fig. 33), with one portion of

each wire left convenient for making connections, we obtain a current possessing the quantity of four pairs, and the intensity of one; and, 3rd, if they are arranged in two series or rows, two pairs in each, each series being connected intensity fashion, the end silvers of each row facing one way and connected by one wire, and the terminal zincs facing the opposite way and connected by another wire, and these wires left free for connection with the vat (Fig. 34), we obtain a current possessing the intensity of two pairs and the quantity of two. By contrivances of connection like these, any number of batteries, provided they are similar in kind, charged alike, and have suitable connecting screws attached, may be connected together so as to give any desired quantity or intensity of current within the limits of their power; thus, a battery of one hundred pairs may be arranged to yield a current having the intensity of one hundred pairs, and the quantity of one; the quantity of one hundred, and the intensity of one; the intensity of fifty, and the quantity of fifty; or any intermediate degree of each.

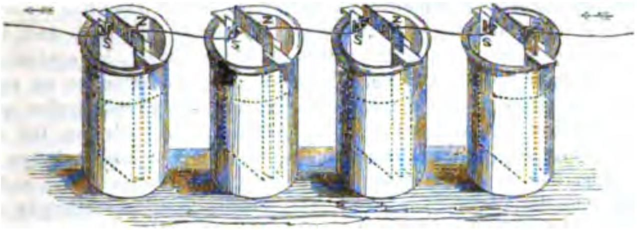

Fig. 32.

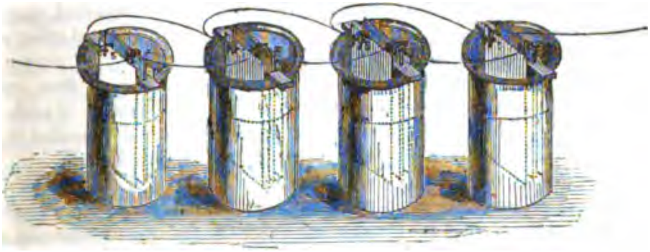

Fig. 33.

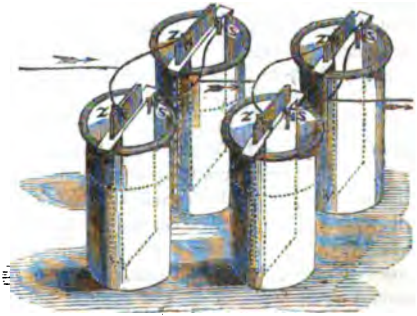

Fig. 34.

189. **Regulating the Quantity of Deposited Metal.**—The quantity of metal dissolved and deposited in the vat, is in direct proportion to the quantity of zinc dissolved

and acid consumed in each alternation of the battery. With a perfect depositing liquid, good battery arrangements, and pure materials, for every equivalent of zinc dissolved in each alternation of the battery, an equivalent of metal is dissolved on one side, and an equivalent deposited on the other, in the depositing vessel. For instance, for every equivalent (32·6 parts) of zinc so dissolved, and 49 parts, or one equivalent, of oil of vitriol consumed in the battery, an equivalent (31·7 parts) of copper is deposited in the sulphate of copper solution, or an equivalent (108 parts) of silver in the cyanide silver plating liquid, and similar quantities of copper or silver dissolved at the anode. But in practical working, the materials are rarely or ever pure, or the arrangements perfect; the zinc nearly always contains a small proportion of other substances, the mercury contains tin or lead, and the sulphuric acid contains a little nitric acid. The acid liquid of the battery is often too strong; much acid liquid is frequently wasted, being thrown away before it is completely exhausted. The zinc plates have not kept well amalgamated, or the silver well platinized, or the plates have been suffered to remain too long in the liquid when not in use. The metal of the anode is frequently impure also; occasionally some of the deposit is allowed to redissolve, in consequence of the battery power becoming low, and from not stirring the solution; in some solutions, a part of the battery strength is expended in evolving gas at the cathode; and, finally, the repeated operation of "scratching" removes some of the deposit. Allowing for all these and other unavoidable sources of loss in practical working, about one pound only of copper can be deposited in the ordinary sulphate solution, by the consumption of from one and a quarter to one and a half pounds of zinc and an equivalent quantity of acid, in each alternation of the battery. To increase the quantity of metal deposited in a given period of time, the battery plates should be sunk deeper in their liquids.

190. *Regulation of the Quality of the Deposit.*—The quality of the deposited metal, *i.e.*, its degree of cohesion, hardness, flexibility, &c., depends upon the intensity of the current. As a general rule, the greater the intensity and the smaller the quantity of the current, the harder and brighter is the deposited metal; and the greater the quantity and the smaller the intensity, the less coherent and the softer it is. To obtain a very hard, bright, and crystalline deposit, we should use a current of small quantity and high intensity; and to obtain a soft black powder deposit, we should employ large quantity and low intensity; the combination of moderate quantity and moderate intensity, produces a coherent reguline deposit, possessing all the ordinary characteristics of the particular metal. These results can only be obtained with a good depositing liquid, and with metals, such as copper, silver, gold, &c., which are known to exist in a tough reguline state, and not with those—such as bismuth or antimony, crystalline metals—which are not known to exist in that state.

191. If we are producing a reguline deposit, with a one pair battery, in a good depositing liquid, with electrodes of the same size as the immersed portion of the battery plates, and it is wished to change the deposit to a soft black powder, the plates of the battery must be immersed many times deeper in the liquid, and use a very much larger dissolving plate in the vat; and if we wish to change the deposit to a crystalline one, several more pairs of battery should be put on, connect them intensity fashion, immerse the plates an exceedingly small depth in their liquids, and use a very small anode. These results have a direct reference to the size of the receiving surface; for if, with any given battery and anode, we are producing a black powder deposit upon a very small article, a larger article would receive a reguline deposit, and a much larger

one would receive a deposit bordering upon crystalline. Thus it will be perceived that the black powder deposit is a result of too rapid action, and the crystalline one of too slow action.

192. *Spread of Deposit.*—If we wish to make a deposit spread rapidly over a metal of inferior conductibility, such as a long iron rod, we must use a current of high intensity and rather small quantity; this will drive it over the surface without causing it to become soft or non-coherent. The action of such a current appears to consist in conferring upon the particles a kind of polarity, a power of grouping themselves into separate warty nodules or crystals, each of which, as it becomes larger, appears to powerfully repel its neighbour, and thus cause the metal to spread rapidly; when this action is continued to a considerable thickness of deposit, especially in cold weather, the metal is exceedingly hard and easily broken into a number of distinct grains or nodules, which are in the form of warty lumps with rounded edges; when the action has been rather too quick, or the liquid not sufficiently cold, and composed of more or less perfect crystals, with edges sometimes beautifully defined, when the action has been very slow, and the liquid very cold and undisturbed. With the intensity of one hundred pairs of Smee's battery, acting for a long period of time in cold weather, and the quantity of the current kept down to the lowest possible degree, we have seen a tough deposit of zinc spread over several square inches of clean gutta-percha; and in depositing copper with a current of rather high intensity, and small quantity, upon blackleaded gutta-percha medallions, we have repeatedly observed, that where there was a sunk boundary line near the edge, the deposit remained quite thin, as if powerfully repelled, whilst on each side of the line it was very thick, and on the outside edge, accumulated in large warty masses, hard and distinctly separate, and containing as much metal as the whole of the medallion besides.

193. **Management of Batteries.**—The most suitable strength of liquid for filling the battery cells consists of one measure of sulphuric acid and about twenty measures of water; a stronger liquid may be used, even to one part of acid to ten or twelve parts of water; but then the zinc plates require constant watching and frequent amalgamating, to prevent waste. If the acid liquid is very strong and the electric action energetic, the zinc plates will require to be examined every day, to see that there is no local action, *i.e.*, chemical action in particular places; and when gas is found to be freely rising from them, as well as from the silver or copper, or when any dull patches appear where the acid has acted too strongly upon them, they should be taken out and amalgamated. They should be frequently amalgamated when new, and afterwards, if much worked, they should be amalgamated every few days; when they become old they should be rarely amalgamated, because it very much weakens the power. When they become so thin as to fall to pieces on handling, new ones should be substituted, and the old ones should either be melted at as low a degree of heat as possible, to prevent loss of mercury, and cast into rods for Daniell's batteries; or be broken up, put in an iron retort, and the mercury distilled from them at a strong red heat into a vessel of water.

194. The zinc plates should be taken out of the liquid every evening, unless deposition is required to continue all night. After the battery has been at work a few days, a little more acid should be added, and the liquid stirred; and this should be done as often as the power gets low, until at length the liquid becomes thick and nearly saturated with zinc salt, and the salt crystallizes about the edges of the cells; it is then time to throw it away and put fresh, or it may be filtered, evaporated, and

crystallized, and the resulting salt (sulphate of zinc) preserved for depositing purposes. If any of the silver or copper plates of the batteries become covered with a deposit of zinc whilst working, it shows that all the acid in that cell is exhausted, and that more should be added, or fresh liquid put in. This only happens in a Smee's battery, or in the old zinc and copper battery. The deposit of zinc may be easily and quickly removed by the addition of acid to that cell, by a fresh liquid, or by immersing the coated plate in dilute sulphuric acid as long as gas is evolved from it.

195. If copper plates are used in the batteries, they should be heated red hot all over every week or ten days, and quenched in water, and then dipped in "dipping liquid" (82), or in nitric acid; and if platinized silver plates are used, they should be re-platinized as often as they become light in colour, or their power becomes low, which will happen once in two or three months with constant working. The re-platinizing greatly increases the power of the battery. Great care must be taken that the zinc plates never touch the silver or copper ones when wet, otherwise the mercury will get upon the latter, and much weaken the battery power; and with the silver plates cause them to drop to pieces if they are very thin.

196. *General Rules for Working Solutions.*—In working any depositing liquid—1st, avoid doing anything which will alter the chemical composition of the liquid, or even the proportions of its ingredients, except the water—that may be altered, in proportion, in most liquids without much inconvenience; 2nd, adapt your electric power to the liquid, rather than the liquid to the power, and regulate the deposit rather by alterations in the battery than by alterations in the depositing vessel, except as regards the distances of the electrodes or the temperature of the liquid—these may be altered with safety, and sometimes with convenience; and, 3rd, as a general rule, let your dissolving metal expose a larger immersed surface than the receiving article.

197. *Position of Articles and Dissolving Plates.*—The best practical position for the dissolving plate is the vertical, the dissolving plate and the receiving article being suspended in the liquid facing each other, the latter being rather the lowest of the two, and both wholly immersed. The horizontal position, with the dissolving metal above, although the most philosophical arrangement, does not succeed in practical working, because the metal used for dissolving, is never quite pure (with copper, especially), and the impurities from it fall upon the surface of the receiving article beneath, and make it rough; in addition to this, the position of the article prevents our being able to examine it easily or remove it conveniently. If the article to be coated has a very irregular outline, either the dissolving plate should be bent somewhat to its form, so that the two may be nearly equi-distant at all parts; or the article should be often shifted in its position, so as to produce a nearly uniform thickness of deposit all over. The nearer the receiving article is to the dissolving plate, the more rapid is the deposit, and a large body of liquid, deposits more rapidly and more evenly than a small one; large connecting wires are more favourable to quick deposits than small ones. The greatest thickness of deposit always takes place upon the most prominent places, *i.e.*, upon those parts nearest the dissolving metal.

198. *Motion of Articles in Vat.*—In some solutions—for instance, the double sulphite of silver and potash—if the current is too strong to produce a good deposit, motion of the articles will prevent the deposit becoming bad. In some plating establishments, the articles in the vats are kept in constant motion, gently swinging to and fro, the metal frame upon which they are suspended having four small wheels running upon

four small inclined planes fixed upon the edges of the vat, which are kept in constant motion by steam or other available power.

199. *Temperature of Solution.*—Several solutions, such as the cyanide of copper and potassium, the cyanide of gold and potassium, &c., require to be kept hot, in order to make them conduct freely, and yield suitable metal; not that they cannot be worked cold, but that they work much better and quicker hot, which more than compensates for the expense of heating them.

200. *Protection of Depositing Liquids from Light.*—Some liquids, such as the double sulphite of silver and potash and the hyposulphite of silver and potash, require to be protected as much as possible from the influence of light; and even the ordinary cyanide silver liquid is better screened from an excess of this agent.

201. *Clean Connections Necessary.*—In every case we must be very careful to observe that the circuit is complete, and that it is capable of conducting the current freely throughout; that the articles to be coated are conductors of electricity; and that their surfaces, as well as all the ends of the wires, at their various points of contact are perfectly clean.

202. *Management of Coppering Liquids.*—With the sulphate of copper solution (120) no particular management is required, beyond the general rules already laid down (196). It is not suitable for depositing direct upon zinc, tin, lead, iron, or steel. Articles formed of these metals are first coated with a thin layer of copper, in the cyanide of copper and potassium solution (120), then well washed, and transferred immediately to the sulphate solution, and the remainder of the required thickness of copper deposited upon it.

203. **Uses of Copper Deposition.**—Among the many uses to which the electro-deposition of copper has been applied, we may mention the following:—To make copper cells for Daniell's batteries; making copies of stereotype plates, engraved copper plates, and engraved rollers; coppering the surface of printing type; coppering steel pens (patented); to protect iron and steel goods from rusting, coating telegraph wires, ship's bolts, screws, &c.; to make copies of Daguerreotype pictures; to make coppered cloth; to coat glass chemical vessels; to coat and protect metal and plaster statues, busts, and sculptured works; to preserve the form of flowers, fruits, ferns, sea-weed, insects, reptiles, &c.; to make medallions, busts, and various figures and ornaments in copper; to etch Daguerreotype pictures; it has also been applied in the arts of glyphography and electro-tint printing.

204. *Making Objects in Copper, Coppering, &c.*—To make a cell of Daniell's battery in copper, coat the inside of a glass jar or earthen jelly pot with wax, resin, or stearine, by making the vessel hot, then either blacklead it thoroughly, or treat it with the phosphorus, silver, and gold solutions; or, what is more simple, coat it uniformly all over the inside with the phosphorus moulding composition (87), and then treat it with the gold and silver liquids. Make a connection by a fine copper wire with the lower part of the coating; fill the vessel nearly full of the sulphate of copper depositing solution (120), suspend in it a sheet of copper, and connect the sheet of copper and the fine copper wire with a small battery of one or two pairs. If, instead of the battery process, we adopt the single cell arrangement, containing dilute sulphuric acid and a piece of zinc, placing a porous cell in the sulphate solution, and connecting the fine copper wire with the piece of zinc; in either case a deposit of copper will soon spread over the entire inside surface of the jar, especially if it has been prepared by the phosphorus method. Engraved steel plates are copied by stopping-off the back with copal varnish, allowing it to become perfectly dry; immersing it in the cyanide coppering

liquid, and depositing a thin film of copper upon it, then washing it well and at once immersing it in the sulphate of copper solution, and depositing the required thickness of copper upon it; this will require from 24 to 48 hours. The surface of the steel should be previously prepared for a non-adhesive deposit, otherwise the two metals cannot be separated.

205. *Copying Wood-cuts in Copper.*—For printing purposes, where a large number of impressions of a particular wood-cut is required, the plan of taking copies of the engraved wooden block in copper by the electro-process, and using those copies instead of the original block to print from, has been gradually extending itself for some years, and has now attained a considerable degree of importance; the vignette at the head of the title-page of the *Illustrated News*, the title-page of *Punch*, many of the large engravings in the *Illustrated News*, and even the illustrations of some of the penny periodicals are regularly produced in this way. To copy an engraved wooden block, the engraved surface is first moistened with water, and firmly enclosed by a shallow frame, a thick piece of gutta-percha, more than sufficient to fill the enclosed space, and made quite soft by heat, is then laid upon it, commencing its contact at the centre of the engraving and proceeding outwards, so as to exclude all air-bubbles; a plate of cold iron is then laid upon the gutta-percha, and the whole subjected to pressure, gentle at first, but increased to a high degree as the substance cools. The block and copy are then separated, and the figured surface of the gutta-percha (with connecting and guiding wires previously attached) is treated in the usual manner with black-lead or with the phosphorus, silver, and gold solutions; copper is then deposited upon it in a solution of sulphate of copper, until a moderate thickness of deposit is obtained, which will occupy at least twelve or eighteen hours; when sufficiently thick the deposit is removed, its back made rigid by a layer of solder or type-metal (the surface being previously moistened with a solution of chloride of zinc to make the solder adhere), the back is planed flat, and mounted upon a block of wood to the height of the type. In London this process is carried on upon a large scale, some of the copies being upwards of two feet square. Engravings upon steel are copied in an exactly similar manner to those upon wood.

We have recently tried some experiments with a view of making the deposit of copper upon gutta-percha and marine glue spread more rapidly than it does, by preparing the surface with blacklead, it being a matter of some importance in copying wood-engravings for periodicals of such large circulation as the *Illustrated News*, that the time occupied in copying them be reduced. Our experiments have resulted in some success, and we give the following results of them for the benefit of the printing trade.

After having formed a reverse copy in gutta-percha and marine glue of the engraved wooden block, and affixed the conducting wires to it, take a mixture of one measure of spirit varnish, and either four or five measures of vegetable naphtha, and apply it very sparingly in a thin layer by a soft camel's-hair brush, over the whole surface of the mould where the deposit is desired to be spread. Whilst the surface is still wet, cover it with a mixture of three parts of yellow and one part of white bronze powder, and bring the powder in thorough contact with the whole of the moistened surface by striking it all over with a dry, soft brush, then gently brush off all the superfluous powder. The bronzed mould may now be immersed in the ordinary sulphate of copper solution, and the following actions will occur:—The particles of white bronze powder being composed almost wholly of tin, and those of yellow bronze containing much copper, those of tin will dissolve and coat themselves with copper by simple immersion process (4), and those of brass or copper (the yellow ones) will become coated by their contact with those of tin (Two Metals and One Liquid Process, 7), and thus a thin deposit of copper will almost instantaneously spread all over the bronzed surface. This effect will of course take place without connecting the mould with the battery, but they may be immediately connected together, and a deposit will spread almost instantaneously over the whole of the bronzed surface by the ordinary battery process, through the medium of the bronze and the thin deposit already mentioned, and may be continued to any required thickness in the usual way. In our earlier experiments with this method, yellow bronze alone was used, which did not reduce the copper by simple immersion; but even then medallions were repeatedly covered with a deposit of copper in from two to five minutes, which would occupy from twenty to forty-five minutes when prepared by blacklead in the usual manner. The addition of white or tin bronze causes the deposit to spread as rapidly as when the surface is prepared by the phosphorus solution, but without the disadvantage which occurs in using the latter, of making the deposited metal brittle. The effect of using white bronze alone was not so satisfactory.

The surface of the copper copy so obtained is bright and clean, and the character of the deposited metal is good, but the surface obtained is hardly so smooth and fine as that obtained with blacklead; the difference, however, is very slight, and it is sufficiently smooth for all ordinary purposes, and for the object sought, if care be taken to blow off or otherwise remove all superfluous bronze powder before immersing the mould in the vat. We hope that those who have the opportunity will try it upon a larger scale.

206. *Copying Set-up Type in Copper.*—The process of electrotyping has also been gradually encroaching upon that of stereotyping, and has, we are informed, almost superseded that process in America. The plan adopted is similar to that of copying woodcuts, viz., to lay a sheet of softened gutta-percha upon the surface of the page of type, and subject it to increasing pressure until it is cold; the gutta-percha copy is then removed, and treated as in copying wood engravings. It would be advisable to try a somewhat softer material for this purpose, such as the mixture of gutta-percha and marine glue, which we have recommended (85). This material takes a sharper and smoother impression than gutta-percha alone, and the deposit spreads over it more rapidly; and, being softer, it would enter more freely and with less pressure between the fine lines of the letters, and still not be sufficiently soft to enter the minute crevices between the body of the types. If a solution of grape-sugar (as used in Drayton's patent process for silvering glass), aldehyde, or other reducing agent, was substituted for the phosphorus solution, for reducing the silver upon the surface of the mould, it would be an advantage, as besides the dangerous character of the phosphorus, it has an offensive odour, and the copper deposited upon surfaces prepared by it, moreover, is invariably brittle.

The mould may also be prepared for a deposit by blackleading; it will require a first-rate quality of blacklead, and prolonged and attentive brushing, but will then afford a good result. The air-bubbles may be removed when the mould is in the liquid, by directing a powerful upward current of the liquid against them by means of a vulcanized india-rubber bladder, with a long and curved glass tube with a fine orifice (Fig. 35) attached to it; but the liquid should be free from sediment.

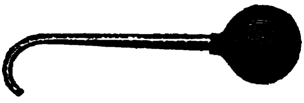

Fig. 35.

The advantages of electrotyping over stereotyping are numerous; the metal is harder, takes a sharper impression of the mould, and delivers the ink much more readily than type metal, besides being a cleaner process; it also takes up less ink, and consequently the printed pages dry more quickly. Both wood-cuts and letter-press have also been copied in plaster of Paris, and the deposit of copper formed upon that; but this material is much inferior to gutta-percha for the process. Messrs. Bradbury and Evans are considered the most successful manipulators in this branch of electro-deposition, and their apparatus the most perfect of its kind. In this establishment the temperature of the room is carefully attended to, and the vessels containing the solutions have glass covers. The result of this careful manipulation has been that, in some instances, successful deposits of large *Illustrated News* engravings have been formed and taken off in eight hours; this can only have been effected by the most perfect blackleading, keeping the solution in excellent condition, and worked with the maximum of battery power. Gutta-percha and marine glue is well worthy of a trial, and the use of bitumen with gutta-percha is also a good idea; the marine glue would be better, because it is tougher.

Iron and steel wire may be coated with an adhesive deposit of copper, by first immersing them, with their surfaces perfectly clean, in the cyanide coppering liquid, and completing the deposit in the ordinary sulphate solution. The coils should be kept separate from each other in the liquid by suspending them upon a horizontal brass rod, turning it occasionally to cause an uniform deposit. Iron screws and nails may be treated in a similar manner except that they should be contained in a wicker basket, and shook about occasionally to produce an uniform deposit.

207. *Copying Daguerreotype Pictures in Copper.*—The most interesting and beautiful application of the deposition of copper, and, at the same time, one of the easiest to be effected, is that of copying Daguerreotype pictures. First solder a wire to the back of the plate near the edge; paint over the back and edges, and allow it to dry; hang it in a clean sulphate of copper solution, which is perfectly free from dust or grease on its surface; and, in the course of twenty or thirty hours, if about two pairs of small Smee's batteries have been used, the deposit will be sufficiently thick to be removed; it should then be taken out, well washed, wiped perfectly dry, and a narrow strip be cut off its edges with a strong pair of scissors; the two may then be easily separated by inserting the point of a knife, or the end of a thin wedge of hard wood, between them at the edges. If the process has been carefully managed, and the original picture is a strong one, a most beautiful and vivid copy will be obtained; and if the picture is not only a strong one, but has also been well fixed by Fizeau's process, a number of successive copies may be taken from it, but their intensity, as well as that of the original, appears to diminish in each succeeding trial. With a vivid original picture, clear solution, very regular and undisturbed action of the battery, and a fine deposit, we have observed a most strange phenomena, viz., the picture has not entirely disappeared, even in twenty hours, although the coating of copper has constantly increased in thickness; the image has penetrated quite through the deposited metal, and appeared upon the back, even upon deposits as thick as an address card. In some cases the figure was optically positive, and in others negative.

208. *Coating Plaster Models, Flowers, and Clay Figures with Copper.*—Busts and other similar objects may be coated by saturating them with linseed oil, then well

blackleading, or treating them with the phosphorus, silver, and gold solutions, attaching a number of guiding wires, connected with all the most hollow and distant parts, and then immersing the object in a sulphate of copper solution containing no free acid, and causing just sufficient copper to be deposited upon them by the battery process to protect them, but not to obliterate the fine lines or features. Flowers, fruits, ferns, sea-weed, insects, &c., may be prepared by the phosphorus, silver, and gold liquids, and the copper deposited upon them, either by the single cell or battery process, in a neutral sulphate of copper solution.

209. *Coppering Cloth.*—To copper cloth, first stretch it upon a sheet of copper slightly curved, so that it may be in close contact with the metal all over; then varnish the back or hollow side of the copper, and deposit on the opposite side, by the battery process, from a sulphate solution not containing much free acid, until the meshes of the cloth are quite filled with copper, and the metal and cloth firmly united together; the deposit may then be removed and well washed; the original sheet of copper should of course be properly prepared for a non-adhesive deposit. Mr. J. Schottlaender took out a patent, December, 8th, 1843, for depositing either plain or figured copper upon felted fabrics. He passes the cloth under either a plain or an engraved copper roller, horizontally immersed in a sulphate of copper solution not containing much free acid, and a deposit takes place upon the roller as it slowly revolves; the meshes of the cloth are thus filled with metal, and the design of the roller copied upon it, the coppered cloth slowly rolled off, and passed through a second and closely contiguous vessel filled with clean water; the roller is properly prepared for a non-adhesive deposit.

210. *Etching Copper.*—In etching a copper plate by galvanism, we first solder a wire on the back, then varnish the back, and cover the front with a thin layer of engravers' etching ground; draw the design upon the front surface with an etching needle, cutting through this material to the clean surface of the copper. Having completed the etching, hang the plate as an anode in the ordinary sulphate of copper solution, opposite a suitable cathode of brass or copper. The current of electricity in passing out of the engraved lines into the liquid, causes the copper in them to dissolve, and thus etches the design in the plate. The different gradations of light and shade are produced by suspending cathodes of different forms and sizes opposite the plate to be etched, in different positions and at different distances from it, thus causing the etching to be of different depths in different parts, the deepest action being always at the parts of the electrodes nearest together.

211. *Glyphography.*—This art consists in varnishing the back of a flat and smooth copper plate, laying first a thin coating of white etching ground upon its front side, and then a layer of black etching ground upon that, engraving the design upon the coating with different engraving tools, then blackleading the whole of the engraved surface, and depositing a thick sheet of copper upon it in a sulphate solution by the battery process; the deposited plate is then removed, its defects corrected, and fixed upon a block of wood in the same manner as a stereotype plate, ready for printing by the ordinary hand-press. This process has been patented, and the patent is worked by Mr. Hawkins, Hatton Garden.

212. **Management of Silver Solutions.**—Silver plating liquids require much more care and attention than the sulphate of copper solution. Articles formed of zinc, iron, or steel, require to be coated with a thin film of copper in the cyanide of copper liquid, before being immersed in the cyanide of silver solution.

Those formed of Britannia metal, tin, or pewter, are taken direct from the hot potash liquid without rinsing in water, and immersed a short time in a cyanide of silver solution containing considerable supplies of free cyanide, a large anode, and a current of considerable intensity from a strong battery is passed through for several minutes until the articles receive a thin deposit of silver; they are then transferred to the ordinary vat to receive the full amount of deposit. Those of lead are first scraped or otherwise made quite clean and bright by mechanical means, and then treated in the same manner as those of Britannia metal. Articles of copper, brass, or german silver, after being properly cleansed, are dipped into the solution of nitrate of mercury (84), or of cyanide of mercury and potassium (84), then rinsed in a vessel of water, and immediately suspended in the depositing vat. The preparation of those articles by immersion in a bath of cyanide of mercury was patented by Dr. H. B. Leeson, June 4th, 1842, and is in use by the electro-platers of Birmingham. If they are immersed without this preparation, the deposited silver does not always adhere firmly.

213. **Peculiarities in Practical Silver Deposition.**—Peculiar phenomena often occur in the electro-deposition of silver, not only upon different metals, but also upon the same metals in different forms or in different conditions of surface; for instance:—

1st. If two perfectly similar pieces of thin sheet brass are taken (except that one is perforated all over with small holes), and both be simultaneously immersed in the same solution to be silvered, and with the same battery power applied to each, the latter, although its amount of surface is reduced by the perforations, will become coated with silver much more slowly than the former:—

2nd. If a wire gauze cylinder of a Davy lamp be suspended side by side with a piece of thin tubing of the same metal and of the same dimensions, the latter will become coated much more rapidly than the former.

3rd. If two pieces of the same metal—iron for instance—be immersed to be silvered in the ordinary cyanide solution, or to be coppered in the hot cyanide of copper and potassium liquid, each containing exactly the same amount of surface to be coated, but one being in the form of a thin sheet, and the other in that of a thick plate or solid block of metal, the former will become coated much more rapidly than the latter.

4th. The edges and points of articles, whilst being plated, exhibit a greater tendency to a crystalline deposit than the flat parts, and this tendency is sometimes manifested in depositing silver upon table-knives and forks. It is the knowledge of these and many other peculiarities of different metals and articles met with in practical working, and of the means of overcoming their attendant difficulties, which constitutes one of the chief differences between the practical operator and scientific man.

214. **Management of "Bright Solution."**—A bright solution is much more difficult to manage than the ordinary silvering liquid; if it is not worked constantly and in an uniform manner, it will lose its power of yielding bright metal. If any of the articles which are being plated in it are disturbed, or removed from the liquid and replaced, that one will not now receive a bright deposit, and the disturbance of the liquid by removing it will oftentimes cause all the neighbouring articles to lose their brightness. If too much "brightening liquid" (144) is added, the solution will be considerably injured; many silver solutions have been irretrievably damaged in this way. A bright solution requires a battery current of large quantity and low intensity to work it, and the dissolving plates in it are generally of a darker colour than those in

the ordinary silvering liquid; the silver deposited from it is much harder than that deposited from the ordinary plating solution, and has very much the appearance of fused metal; the bright appearance commences at the upper part of the articles and travels downwards, it soon after commences also at their lower extremities and travels upwards, until the bright portions meet each other. If there are very small holes in the surface of the articles, dull streaks appear above them.

215. **Adding Cyanide of Potassium to Plating Liquids.**—It is necessary to add a little cyanide of potassium occasionally to every cyanide of silver plating liquid, probably because the solutions absorb carbonic acid from the atmosphere, which converts some of the cyanide of potassium into carbonate of potash, and sets hydrocyanic acid gas free. A further portion of the potassium salt may also be decomposed by some means, with formation and escape of ammonia; the necessity of adding a little fresh cyanide is indicated when the dissolving plate begins to change from its ordinary pure white appearance to a dull yellowish gray colour; it is best added in the evening after plating; about half an hour before stirring the solution.

216. If the solution is too strong, *i.e.*, if it contains insufficient water, but has silver and cyanide of potassium in their proper relative proportions, it conducts freely, deposits rapidly, and gives a rich deposit of a fine silky lustre; but it is more difficult to manage than a weaker liquid, especially in hot weather, because, from the less mobility of its particles, it is very apt to settle by working into strata of different densities, its upper part becoming exhausted of silver and full of free cyanide, and its lower part becoming nearly saturated with that metal, and destitute of free cyanide; the consequence of this is, that the upper parts of the dissolving plates waste rapidly, whilst the upper parts of the article receives either very little deposit, or one of a bad quality, being gray, brown, or yellowish, sometimes of a lilac hue, and generally in dull streaky vertical lines; all these evils may be mitigated by stirring the solution well every night after having finished plating, or it may be entirely prevented by diluting the liquid with water to a proper extent, stirring it every evening, and working it uniformly. All silvering and other depositing liquids exhibit this tendency to settle into strata in working, especially if worked rapidly, but the most dilute ones shew it in the least degree.

If the solution is deficient in water, and contains a great excess of free cyanide, the foregoing evils are all greatly aggravated. In hot weather it becomes quite unmanageable, and the vapours of ammonia and hydrocyanic acid arising from it are quite overpowering. In this case, the best way to improve it is to add cyanide of silver and water in sufficient quantities to make it of a good composition, keep it in a cool place, stir it daily, and work it constantly in an uniform and careful manner. New solutions, or old ones which have been injured, often improve by daily stirring, with uniform and judicious working. An excess of cyanide of potassium is indicated when the dissolving plates are very strongly acted upon, and the deposit is at the same time either very sparing or of a bad colour.

If the solution is too weak, *i.e.*, if it contains too much water, it conducts sparingly, deposits slowly, and the deposit has a dead white appearance. This may be easily remedied by adding cyanide of silver and cyanide of potassium to it in proper proportions, and working it uniformly a few days with daily stirring.

217. **Washing, Drying, and Ornamenting Silver-plated Articles.**—Articles that have been plated with silver are always washed in a running stream of water until every trace of the depositing liquid is removed from them; they are then immersed in hot dry sawdust, moved about in it and gently rubbed with it, until

they are perfectly dry. After drying they are, if necessary, weighed, to ascertain how much silver has been put upon them, then "scratched" (80), and finally finished by burnishing, polishing, &c.

Sometimes, for the purpose of ornament, portions of their surface are "oxidized." This is done by applying a hot solution of bichloride of platinum (167) to them, and allowing it to dry. The more platinum the solution contains, and the hotter it is, the deeper black does it produce; or it may be effected by the application of the solution of "liver of sulphur.". To produce a brownish colour, apply a solution of equal weights of sulphate of copper and sal-ammoniac in vinegar; and to produce a "dead" appearance, like frosted silver, deposit a mere trace of copper upon it in a copper solution, then well wash it, and deposit a very thin layer of silver upon this. In each of these cases the parts which are to remain bright must be stopped-off with varnish.

218. **"Stripping" Silver from Copper and Copper from Silver.**—Occasionally the depositor has sent to him, to be re-plated, old worn-out articles formed of "Sheffield plate," in which the outer layer of silver has been worn away, and exposed portions of the copper base beneath; these articles generally require to have the remaining portions of silver removed, in order to obtain an uniform surface to deposit upon. The removal of the silver is termed "stripping." To effect this, add a little nitrate of potash (saltpetre) to a quantity of strong oil of vitriol, and apply heat, until it is all dissolved; then immerse the articles in the hot liquid, and allow them to remain until all the silver is dissolved. If the action becomes slow, apply more heat or add more saltpetre, the copper will not be much acted upon if the articles are not allowed to remain in too long. A number of such articles are generally done together, and are afterwards washed, and prepared in the usual manner for receiving a deposit. The silver may be recovered from the liquid, in the form of chloride of silver, by diluting it with much water, then adding a solution of common salt to it as long as a precipitate is produced; the precipitate, when washed and dried, is chloride of silver. By fusing this with carbonate of potash the metallic silver is obtained.

To remove copper from silver (which is but rarely required), boil it in dilute hydrochloric acid, or immerse it in a hot solution of perchloride of iron. This latter solution may be made by adding peroxide of iron (crocus, jeweller's rouge) to hydrochloric acid as long as it will dissolve; it will remove either tin, lead, or copper, from either gold or silver, without affecting those metals. A solution of chloride of zinc has been used for the same purpose. Copper may also be completely removed from silver or gold, by making it the anode in a sulphate of copper solution until all the copper is dissolved; the silver will remain unaffected, if the current employed is feeble and has not a greater intensity than one or two pairs.

219. *Testing the Purity of Silver.*—M. Runge adopts the following method of testing the purity of silver:—He immerses the article in a mixture of 32 parts of water, 4 parts of sulphuric acid, and 3 parts of chromate of potash. If pure metal, the immersed part quickly assumes a purple colour, which is less deep and less lively in proportion to the amount of alloy contained in the silver. No other metal exhibits the same colour with this liquid.

220. *Testing the Amount of Silver and of Free Cyanide in Silver Solutions.*—To ascertain the amount of silver in a cyanide plating solution, add dilute sulphuric acid to a known quantity of the liquid as long as it produces a precipitate; wash and dry the precipitate, which is cyanide of silver, containing in every 134 parts, 108 parts of

metallic silver. To test the amount of *free* cyanide of potassium, add a solution of crystallized nitrate of silver in distilled water to a known quantity of the plating liquid, as long as the precipitate formed continues to be re-dissolved, and note how much crystallized nitrate is used; every 175 parts expended, indicate 130 parts of free cyanide, or about three parts of free cyanide to four parts of nitrate of silver.

221. **Management of Gilding Solutions.**—Cyanide gilding solution is generally contained in a glazed iron vessel, and heated either by a stove or by gas jets beneath; or it is contained in a stoneware or glass pan immersed in boiling water. On account of the general smallness of the articles to be gilded, the thinness of the deposit required, and the rapidity of the action in a hot liquid, the articles only require to be immersed in the solution for a few minutes; when a thicker deposit is required, in order to maintain a proper condition of deposit, they should be taken out several times, brushed, and re-immersed. Articles formed of iron or steel are required to be coated with a thin film of copper in the cyanide coppering liquid before gilding. The strength of battery used for gilding is generallyabout two pairs of Smee's, of different sizes, according to the magnitude of the articles to be gilded. The loss of water by evaporation is generally made good by adding a little distilled water, after having finished gilding.

222. *Regulation of Colour in Electro-gilding.*—The general method now adopted for regulating the colour of electro-gilding is as follows:—After having prepared the solution, work it with a large copper anode until the deposited metal begins to deteriorate in colour; then replace the copper by a small gold anode. With the copper anode can be obtained a rich full colour, becoming deeper as the temperature of the liquid is higher; to produce a paler yellow, use a small gold anode with the liquid at a lower temperature.

223. **Recovery of Gold and Silver from Depositing Liquids.**—As both silver and gold solutions occasionally get out of working condition and become quite unfit for use, it is very desirable that the operator should understand the chemical action of different substances upon them, and how to recover the metal. Those of silver generally get out of order, either from the addition of too much "brightening liquid;" from excess of cyanide of potassium, together with the heat of the weather, and injudicious management; from unsuccessful attempts to improve the condition of the liquid; from the accidental introduction of impurities; or from the liquid having been improperly made. Supposing it to be the usual cyanide liquid, the silver may be recovered in the metallic state thus:—Evaporate the solution nearly to dryness, reduce the resulting salt to powder, mix it with its own weight of a mixture of one part of nitrate of potash and two parts of common salt, and roast the whole in an iron pan to dryness. Fuse the dried mixture at a bright red heat in an earthen crucible, until the silver collects at the bottom of the vessel in a melted state, then pour it slowly into a large quantity of water. The resulting granules of silver should not be used in making a new plating liquid, because they generally contain copper derived from the articles suspended in the plating solution (see 151), but should be exchanged at a silver refiner's for pure silver.

224. "The crystallized double cyanide of gold and potassium fuses and effervesces by heat, and is resolved into cyanogen gas, ammonia, and cyanide of potassium, if air be present; its complete decomposition requires a strong red heat. When it is strongly ignited, mixed with an equal weight of carbonate of potash, a button of metallic gold is obtained. When heated with sulphuric acid, it gives off hydrocyanic

acid gas, and, after ignition, leaves a mixture of gold and sulphate of potash. Iodine sets free cyanogen gas, forms iodide of potassium, and throws down the cyanide of gold. The aqueous solution of cyanide of gold and potassium gilding liquid, when mixed with sulphuric, hydrochloric, or nitric acid, slowly deposits cyanide of gold; and, when boiled with hydrochloric acid, it is completely resolved into cyanide of gold and chloride of potassium. Similar effects are produced by sulphuric or nitric acid, and even by oxalic, tartaric, and acetic acid."

225. *Extraction of Gold and Silver from Exhausted Solutions.*—"To obtain the remaining gold from gilding solutions which have become inactive, they should be evaporated to dryness, the residue finely powdered and intimately mixed with an equal weight of litharge, fused at a strong red heat, and the lead extracted from the alloy button of gold and lead by warm nitric acid; the gold will then remain as a loose yellowish-brown spongy mass."

226. The following extracts are from the works of Boettger, J. Pr. Chem. 36, 169; Elsner, Redtel, Hessenberg, J. Pr. Chem., and other foreign writers:—"I have undertaken a series of researches upon this object, and hasten to communicate the results to the public; but, before proceeding to the communication, I think it necessary to mention the results of the experiments upon which are based the methods given further on for extracting both the silver and the gold of old cyanide of potassium liquids.

227. "1st. If we add hydrochloric acid to a solution of silver in cyanide of potassium, until the liquid exhibits an acid reaction, we obtain a white precipitate of chloride of silver, which, when submitted to heat, melts into a yellow mass. If this was cyanide of silver, the application of a red heat would have left a regulus of silver. The addition of the hydrochloric acid precipitates all the silver present in the liquid in the form of chloride of silver.

228. "2nd. If we evaporate a solution of silver in cyanide of potassium to dryness, and heat the residue to redness until the mass is in a state of quiet fusion, and has assumed a brown colour, there remains, when we wash the mass with water, metallic and porous silver. The wash-waters, when filtered, still contain a little silver in solution; because, if hydrochloric acid is added to them, it produces a precipitate of chloride of silver. In evaporating and calcining a solution of gold in cyanide of potassium the result is the same—we obtain metallic gold. The wash-waters, acidulated with hydrochloric acid, give, when treated with sulphuretted hydrogen, a brown precipitate of sulphide of gold; and, with the salt of tin, a violet precipitate purple of cassius,—a proof that these liquids still contain a little gold in solution.

229. "3rd. If we pour upon finely-divided silver—for instance, silver-leaf, or silver precipitated in the porous state by zinc from a solution of silver—a concentrated solution of cyanide of potassium, at the ordinary temperature, and shake it frequently, the liquid, at the end of a certain time, exhibits silver in solution, and by adding hydrochloric acid to it, we produce an abundant precipitate of chloride of silver. This experiment explains why, in the wash-waters of the various combinations of gold or silver with cyanide of potassium, we can still demonstrate the presence of gold and of silver, after the most minute separation.

230. "4th. When hydrochloric acid or ordinary sulphuric acid is added to a solution of cyanide of copper and cyanide of potassium, until the liquid exhibits an acid reaction, there results a reddish-white precipitate, which is a cyanide of copper in the anhydrous state. If the precipitate be well washed and boiled in potash lye, protoxide of copper is separated of a beautiful red colour; and if to the filtered alkaline liquid we add a solu-

tion of green copperas, a dirty blue precipitate is obtained. A solution of carbonate of soda furnishes the same results, and yields, with the copperas, the same dirty blue precipitate. If the reddish-white precipitate is dissolved in pure nitric acid, and a solution of nitrate of silver added to it, an abundant white precipitate is produced, which, when washed, dried, and calcined, yields silver in the metallic state—a proof that the precipitate is cyanide of silver.

231. "The reddish-white precipitate is soluble in an excess of hydrochloric acid, in nitric acid, and in aqua regia; it is also soluble in aqueous ammonia and in a solution of cyanide of potassium.

232. "5th. If we pour hydrochloric acid into a very pure solution of gold in cyanide of potassium, there is slowly formed at ordinary temperatures, and immediately on the application of heat, a yellow precipitate, which is cyanide of gold; the filtered liquid which has given this precipitate, still contains a little gold in solution. In evaporating to dryness, fusing, dissolving, and filtering a-fresh, there remains upon the filter the remainder of the gold.

233. "When a solution of silver prepared for silvering articles of bronze or of brass, has been employed a certain time for that purpose, the precipitate produced in it by the addition of hydrochloric acid, is not pure white, but reddish, in consequence of the reddish-white cyanide of copper which is precipitated with it; for we know that those silvering liquids which have been used for some time, contain copper in solution. The same thing occurs with the solutions for gilding, in which articles of silver, copper, bronze, and brass, have been gilded for a long time; the liquid contains, after a certain time of service, not only gold, but also silver and copper. This case presents itself especially when gilded articles of silver, containing copper or other alloys of silver, are in the solution of gold; then, the precipitate of cyanide of gold produced by the addition of hydrochloric acid, does not possess its proper pure yellow colour. It has happened to me to observe a precipitate of this kind, which instead of being yellow, was green; and, in fact, articles of iron have been gilded in a solution, and the precipitate contained, besides cyanide of gold, Prussian blue, so as to be demonstrated in an examination, which consisted in boiling the green precipitate in aqua regia, filtering to separate the dirty green residue, evaporating the filtered liquid to dryness, and dissolving the dry salt in water acidulated with hydrochloric acid; the addition of sulphate of iron to this new liquid gave a brown precipitate, and the salts of tin a reddish-brown precipitate. In treating by aqua regia, the cyanide of gold was then decomposed, and converted into chloride of gold.

234. "Based upon the preceding facts we may found several methods for recovering all the silver and gold of old cyanide of potassium solutions. The extraction of these precious metals may be effected either by the wet or by the dry process.

235. "*Extraction of Silver by the Wet Method.*—Adding hydrochloric acid until the liquid exhibits a strongly acid reaction (230). The precipitate of chloride of silver which is thus obtain will be, as we have already said, of a reddish-white colour, because of the cyanide of copper which is precipitated with it when the solution has been used a long time for silvering objects containing copper. In this precipitation by hydrochloric acid there is hydrocyanic acid gas set free, therefore the operation should only be performed in the open air, or in a place where there is good ventilation. If the precipitate is very red it must be treated with hot hydrochloric acid, which will dissolve the cyanide of copper. The chloride of silver having been washed with water, must be

dried, fused with potash in a Hessian crucible, and then coated with borax, in the ordinary manner for obtaining metallic silver.

236. "This method is very simple in its application, and very economical, considering that by the aid of the hydrochloric acid all the silver contained in the solution of cyanide of potassium is precipitated, and there remains no trace of it in the liquid. But the large quantity of hydrocyanic acid gas which is disengaged, is a circumstance which must be taken into serious consideration when operating on large quantities of silver solution, the vapour of which is most deleterious, and nothing but the most perfect ventilation, combined with arrangements for the escape of the poisonous gases, will admit of the process being carried on without danger to the workmen; when, however, we have taken the precautions dictated by prudence, the method in question may be considered as perfectly practical. The liquid should be poured into very capacious vessels, because the addition of the acid produces a large amount of vapour.

237. "*Extraction of Silver by the Dry Method.*—The solution of cyanide of silver and potassium is evaporated to dryness, the residue fused at a red heat, and the resulting mass, when cold, is washed with water. The remainder is the silver in a porous metallic condition. There still remains in the wash-waters a little silver, which may be precipitated by the addition of hydrochloric acid.

238. "*Extraction of Gold by the Wet Method.*—A solution of gold and cyanide of potassium, which has long served for gilding articles of silver alloyed with copper, may still contain, as we have already remarked, independently of the gold, both silver and copper, and perhaps iron. In order to obtain these metals we operate in the following manner:—

"The liquid, the same as with the solution of silver, is acidulated with hydrochloric acid; in which case there is produced a disengagement of hydrocyanic acid gas, which requires the same careful ventilation. This addition of hydrochloric acid causes a precipitate, which may, according to circumstances, consist of cyanide of gold, cyanide of copper, and chloride of silver. The precipitate, washed and dried, is boiled in aqua regia, which dissolves the gold and copper in the form of metallic chlorides, and leaves the chloride of silver unaffected. The solution, containing the gold and the copper, is evaporated nearly to dryness in order to drive off any excess of acid, it is then dissolved in a small quantity of water, and the gold precipitated from it by the addition of protosulphate of iron in the state of a brown powder. The chloride of silver is reduced to the metallic state by the known means. The liquid from which we have precipitated the cyanide of gold, &c., by hydrochloric acid, may yet contain a little gold in solution. I refer to 5th for its further treatment.

239. "This method is distinguished by the great simplicity of the operation, and we may repeat for it all that we have already said respecting the extraction of silver by the wet method.

240. "*Extraction of Gold by the Dry Method.*—The solution of cyanide of potassium which contains gold, silver, and copper, is evaporated to dryness; the residue fused at a red heat, cooled and washed (the wash-waters still contain a little gold and silver, and this occurs most often when the solution of gold or silver contains a very great excess of cyanide of potassium). The residue, after washing, consists of gold and silver in a metallic porous state, and carbide of copper resulting from the decomposition of cyanide of copper by the heat. The metallic residue is treated by aqua regia, which forms insoluble chloride of silver, and contains the chlorides of gold

and copper in solution. In order to obtain these metals in the metallic state, we must proceed in the manner previously indicated.

241. "If we operate according to the method of Professor Bœttger, *i.e.*, if we fuse the dried residue with its own volume of litharge, in a covered crucible, the regulus we obtain in this case consists of gold, silver, and lead. In treating this alloy by nitric acid of specific gravity 1·2, and applying heat, the gold remains in the form of a brown powder, whilst the lead and the silver are dissolved in the acid. This solution, after having been diluted with distilled water, may have the silver separated from the lead, by the addition of hydrochloric acid.

242. "These methods of extracting the silver and gold from old solutions of cyanide of potassium by the dry process present this advantage, that the operator is not incommoded, while working, by the disengagement of vapours of hydrocyanic acid. In these operations the poisonous gases are not developed as they are in the processes for extracting the metals by the wet process.

243. "After the experiments here reported, those who are interested in the subject may choose for themselves which of these methods appear the most suitable to the circumstances in which they are placed, and the object which they wish to attain.

244. "*Means of Recovering Gold or Silver, by M. Bolley.*—Cyanide of gold dissolved in an excess of cyanide of potassium, resists all the means which we have tried to separate them; and hydrosulphuric acid, for example, does not produce a precipitate. By the wet way we cannot always precipitate the gold completely, and for that reason M. M. Bœttger, Hessenberg, Elsner, and others, propose to evaporate the liquid to dryness; mix the residue with its own weight of litharge, fuse the mixture at a strong red heat, then dissolve the lead from the alloy by boiling it a long time with dilute nitric acid, which leaves the gold in the form of a light sponge.

245. "M. Wimmer has more recently proposed to evaporate the solution to dryness in a water bath, then mix the residue with one and a half times its weight of saltpetre, and introduce the mixture by small portions at a time into a Hessian crucible, heated to redness in order to cause explosions, and to continue this until the entire mass is in a state of quiet fusion.

246. "The first of these two processes does not give room for any objection, except the employment of a great heat, and the use of nitric acid; the second process is, on the contrary, disagreeable, and very uncertain. We know that saltpetre never explodes with more violence than with cyanide of potassium; and, notwithstanding that the inventor of the process advises us not to add more than small portions of the mixture at a time, the explosions are so powerful that they cannot be caused without loss of materials.

247. "The following process is applicable on the small scale with a spirit lamp and a crucible of platinum:—Evaporate the solution to dryness, mix the saline mass with its own weight of sal-ammoniac, and heat it gently; ammoniacal salts decompose, as we have said, the metallic cyanides, and form cyanide of ammonium, which is itself decomposed by the heat and volatilized, whilst the acid of the ammoniacal salt (the body which salifies the ammonia) combines with the metals (passed to the state of oxides), which were previously united to the cyanogen. The sal-ammoniac then in this case forms chloride of potassium and chloride of gold, and if the salt contains ferrocyanide of potassium, chloride of iron in addition. The chloride of gold is easily decomposed; the chloride of iron is partly decomposed, and leaves oxide of iron in beautiful crystalline spangles. The undecomposed portion of the chloride of iron,

like the chloride of potassium, may, after the decomposition is finished (which only requires a low red heat), be washed away by water, leaving the gold in the form of a light coherent mass, and the iron in small spangles, which may be removed by mechanical means.

248. "If we fear that a little of the gold remains mixed with the iron in a pulverulent state, we may dissolve it in hot aqua regia, and precipitate the gold from the resulting solution by adding to it a solution of protosulphate of iron; but this appears superfluous; and I am assured, by evaporation of given volumes of the same solution of gold, the evaporation and calcination of the sal-ammoniac, and other operations, that we have collected in a sufficiently exact manner all the gold of these solutions.

249. "The same process is applicable to the solution of silver, and independently of the oxide of iron (of the ferrocyanide of potassium) we obtain chloride of silver, which is soluble in aqueous ammonia

250. **List of Patents upon Electro-deposition.**—The following is a chronological list of nearly all the patents which have been taken out for subjects connected with electro-deposition.

Elkington's Patent.—June 24th, 1836, gilding copper, brass, and other metals, G. R. Elkington.

Elkington's Patent.—February 17th, 1837, gilding metals, and coating with platinum, apparatus described, H. Elkington.

Elkington's Patent.—December 4th, 1837, gilding and silvering certain metals, apparatus described, H. Elkington.

Elkington and Barratt's Patent.—July 24th, 1838, coating and colouring certain metals, G. R. Elkington and O. W. Barratt.

Elkingtons' Patent.—March 25th, 1840, coating or plating certain metals, G. R. Elkington and H. Elkington.

Parkes's Patent.—March 20th, 1841, production of works of art by electro-deposition, Alexander Parkes.

Barratt's Patent.—September 8th, 1841, deposition of metals, O. W. Barratt.

Fox Talbot's Patent.—December 9th, 1841, coating and colouring metals with other metals, H. H. Fox Talbot.

Zeeson's Patent.—June 1st, 1842, electro-deposition, with apparatus, H. B. Zeeson.

Tuck's Patent.—June 4th, 1842, coating metals with silver by electro-deposition. E. Tuck.

Woolrich's Patent.—August 1st, 1842, coating metals and alloys with metal, J. S. Woolrich.

Sturges's Patent.—August 10th, 1842, making plated articles, R. F. Sturges.

Fox Talbot's Patent.—November 25th, 1842, coating metals with other metals, H. H. Fox Talbot.

Moses Poole's Patent.—May 25th, 1843, deposition of metals, with apparatus, Moses Poole.

Barratt's Patent.—June 15th, 1843, gilding and plating metals, O. W. Barratt.

Schottlaender's Patent.—December 8th, 1843, deposition of metal upon felted fabrics, J. Schottlaender.

Parkes's Patent.—February 21st, 1844, deposition of metals and alloys, A. Parkes.

Parkes's Patent.—October 24th, 1844, depositing metals and their alloys, A. Parkes.

Parkes's Patent.—October 9th, 1845, coating metals and alloys, A. Parkes.

Lyons and Millward's Patent.—March 23rd, 1847, deposition of metals, Lyons and Millward.

Salzede's Patent.—September 30th, 1847, brassing and bronzing steel, iron, zinc, lead, and tin, Charles de la Salzedc.

Fontainemoreau's Patent.—March 14th, 1849, coating metals and non-metallic substances, Fontainemoreau.

Russell and Woolrich's Patent.—March 19th, 1849, coating iron and other metals with metals and alloys, Russell and Woolrich.

Parkes's Patent.—March 26th, 1849, deposition of certain metals and alloys, A. Parkes.

Smith's Patent.—June 7th, 1849, depositing metals, S. B. Smith.

Roseleur's Patent.—March 23rd, 1850, tinning metals, A. G. Roscleur.

Steele's Patent.—August 9th, 1850, coating metals, Joseph Steele.

Ridgway's Patent.—April 20th, 1852, coating glass with metal by battery process, J. Ridgway.

Lyons's Patent.—October 7th, 1852, coating surfaces of iron, M. Lyons.

Morriss and Johnson's Patent.—December 11th, 1852, deposition of brass and alloys, Morriss and Johnson.

Junot's Patent.—December 28th, 1852, reducing metals by electricity and plating, C. J. E. Junot.

Power's Patent.—December 29th, 1852, silvering metals and glass, J. Power.

Newton's Patent.—July 29th, 1853, improvements in depositing metals and alloys of metals, W. E. Newton.

Newton's Patent.—August 5th, 1853, coating cast iron with metals and alloys, W. Newton.

Person's Patent.—April 27th, 1854, electro-coating with zinc, C. C. Person.

251. **List of Published Books, &c., upon Electro-deposition.**—Shaw's "Manual of Electro-metallurgy;" Smee's "Electro-metallurgy;" Napier's "Electro-metallurgy;" Walker's "Electrotype Manipulation;" Sturgeon's "Art of Electrotyping;" Spencer's "Instructions for the Multiplication of Works of Art by Voltaic Electricity;" "Manuel Complet de Galvanoplastie," par M. L. de Valicourt, nouvelle édition, 2 vols., 5 francs; "Traite de Galvanoplastie," par J. L. 2e édition, revue et augmentee, 2 fr. 50 c.; "Manuel de Dorure et D'Argenture par la Methode Electro-chimique et par Simple Immersion," par M. M. Selmi et De Valicourt, 1 vol., 1 fr. 75 c.; a paper "On the Cyanides of Gold and Silver," by Messrs. Glassford and Napier, in the Philosophical Magazine, 1844; and the following papers by G. Gore:—"Inductive View of Electro-deposition," Pharmaceutical Journal, July 1853; "Electrical Relations of Iron and Copper," Pharmaceutical Journal, September 1853; "Deductive View of Electro-deposition," Pharmaceutical Journal, April 1854; "On à Peculiar Phenomenon in the Electro-deposition of Antimony," Philosophical Magazine, January 1855; also in Journal de Pharmacie et de Chimie, April 1855; and a series of articles, "Practical Rules and Recipes in Electro-deposition," Pharmaceutical Journal, April, May, July, August, September, October, November, and December, 1855.

252. To further assist the reader in remembering the terms applied to the different parts of the electric circuit (see 39 and 42), and in understanding the action of electricity upon liquids, we repeat those terms, and append a diagram of the anode, cathode, &c.

S is a wire proceeding from the silver plate or positive pole of a battery; Z is another wire from the zinc plate or negative pole; the two wires are attached to two pieces of metal immersed in a depositing liquid. By the direction of the arrows, it will be perceived that the positive electricity circulates in one direction through the circuit, and the negative electricity in the opposite direction.

The immersed pieces of metal are termed "electrodes," meaning ways by which the electricity enters and leaves the liquid; the piece A is called the "anode," and is that by which the positive electricity enters the liquid; and C is the "cathode," or that by which the positive electricity leaves the liquid. In the ordinary depositing vat, the anode is that piece of metal which dissolves and supplies the solution, whilst the article or articles which are receiving a metallic coating or deposit constitute the cathode. The liquid is termed an "electrolyte," and whilst the electric current is passing through, it is said to be undergoing "electrolysis," to be "electrolyzed," or suffering "electro-chemical decomposition." The elements of the liquid are termed "ions;" those of them which combine with, or are set free at the "anode," are called "anions," and those which combine with, or are set free at the "cathode," are termed "cathions;" for instance—1st, in the electrolysis of a solution of sulphate of copper with copper electrodes, sulphuric acid is viewed as an anion, because it is the element which combines with the anode, and copper the cathion, because it is the element set free at the cathode; and, 2nd, in the electrolysis of the ordinary cyanide silver-plating liquid, cyanogen is the anion and silver the cathion.

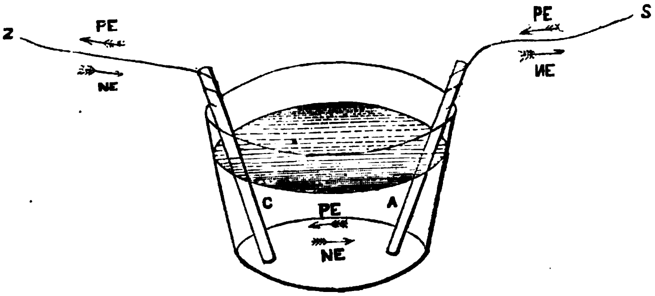

Fig. 36.

GEORGE GORE.

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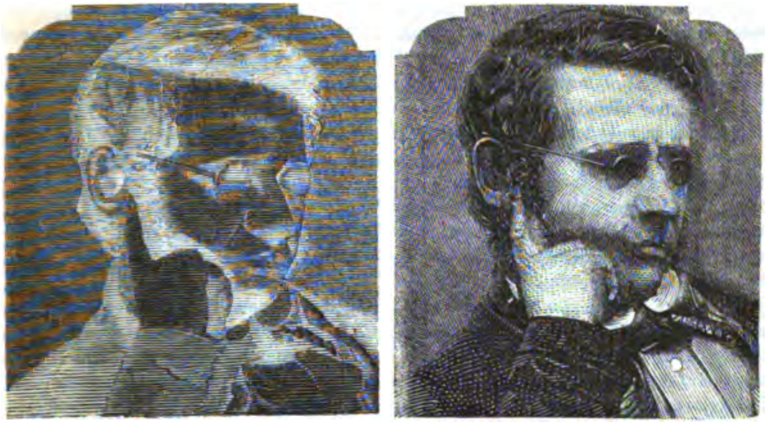

NEGATIVE. POSITIVE.

PHOTOGRAPHED UPON THE WOOD WITHOUT PENCILLING.

PHOTOGRAPHIC ART.

Introduction.—Within the last quarter of a century there has not been a discovery more useful, interesting—I may say, more fascinating—than photography. Whether employed as an assistant to the artist, or a means of sending home from far-off scenes of war and death the portrait of a friend, or the spot whereon, perhaps, he died or conquered, what can equal its truthfulness? what can surpass its beauty? By the aid of the sunbeam the physician may now delineate the gradual changes produced by disease, with a faithfulness hitherto unknown; the architect can obtain the most elaborate details of a building in a few seconds. The art has been made subservient to the purposes of the artist, the naturalist, and the mechanic, and even to the antiquary, who,

> "Bending o'er some mossy tomb
> Where valour sleeps,"

may be enabled to preserve a lasting memorial by this art. Viewed in these lights, Photography may justly be considered the most important application of chemical philosophy to develop the powers of nature which modern science has discovered. Premising that the science is at present in its infancy, I shall endeavour to make the present manual as plain, as practical, and as comprehensive as possible, saying nothing, which might require to be afterwards unsaid, nor leaving anything unsaid which may be necessary to elucidate the subject, so far as our present knowledge extends.

Wedgwood's Discovery.—The property possessed by the salts of silver, when decomposed by the action of light, was well known to the earlier chemists; and M. Charles, a well-known French physician, exhibited in his lectures at the Louvre a paper capable of taking silhouette figures by the action of solar light, but he has left no account of his process. Mr. Wedgwood, therefore, was undoubtedly the first person who recorded his attempts to use the sunbeams for photographic printing. In the year 1802 he published a paper in the Journal of the Royal Institution, which he describes as "an account of a method of copying paintings upon glass, and of making profiles by the agency of light upon nitrate of silver, with observations by H. Davy,"—a gentleman afterwards better known as Sir Humphry Davy. From this paper, the earliest we are acquainted with in which the discovery of these processes present themselves, the following extracts are taken:—

"White paper, or white leather, moistened with a solution of nitrate of silver. undergoes no change when kept in the dark; but on being exposed to the day-light it speedily changes colour, and after passing through different shades of gray and brown, becomes at length nearly black. The alterations of colour take place more speedily in proportion as the light is more intense. In the direct beam of the sun, two or three minutes are sufficient to produce the full effect; in the shade, several hours are required; and light transmitted through different coloured glasses act with different degrees of intensity. Thus it is found that red rays, or the common sunbeams passed through red glass, have very little effect upon it. Yellow and green are more effective, but violet or blue produce the most powerful and decided effect."

"When the shadow of any figure is thrown upon the prepared surface, the part concealed by it remains white, and the other parts speedily become dark. For copying paintings on glass, the solution should be applied on leather; and in this case it is more readily acted on than when paper is used. After the colour has been once fixed on the leather or paper, it cannot be removed by the application of water, or water and soap, and it is in a high degree permanent. The copy of a painting or the profile, immediately after being taken, must be kept in an obscure place; it may, indeed, be examined in the shade, but in this case the exposure should be only for a few minutes; by the light of candles or lamps, as commonly employed, it is not sensibly affected. No attempts that have been made to prevent the uncoloured parts of the copy or profile from being acted upon by light, have as yet been successful. They have been covered by a thin coating of fine varnish, but this has not destroyed their susceptibility of becoming coloured; and even after repeated washings, sufficient of the active part of the saline matter will adhere to the white parts of the leather or paper to cause them to become dark when exposed to the rays of the sun. Besides the applications of this method of copying that have just been mentioned, there are many others; and it will be useful for making delineations of all such objects as are possessed of a texture partly opaque and partly transparent. The woody fibres of leaves, and the wings of insects, may be pretty accurately represented by means of it; and in this case it is only necessary to cause the direct solar light to pass through them, and to receive the shadows upon leather.

"The images formed by means of a camera obscura have been found to be too faint to produce, in any moderate time, an effect upon the nitrate of silver. To copy these images was the first object of Mr. Wedgwood in his researches on the subject; and for this purpose he first used nitrate of silver, which was mentioned to him by a friend as a substance very sensible to the influence of light; but all his numerous experiments as to their primary end proved unsuccessful. In following these processes, I have found that the images of small objects, produced by means of the solar microscope, may be copied without difficulty on prepared paper. This will probably be a useful application of the method; that it may be employed successfully, however, it is necessary that the paper be placed at but a small distance from the lens."

Here we have the first indication of this great discovery. Subsequently, about the years 1810-11, Seebeck made some interesting discoveries as to the production of colour on chloride of silver by solar radiations, the violet rays rendering it brown, the blue producing a shade of blue, the yellow preserving it white, and the red constantly giving a red shade to that salt.

Berard's Discovery.—In the year 1812, M. Berard brought the result of some valuable researches before a commission composed of MM. Berthollet, Chaptal, and Biot, who state in their report that M. Berard had discovered that the chemical intensity was greatest at the violet end of the spectrum, and that it extended, as Ritter and Wollaston had previously observed, a little beyond that extremity. When he left substances exposed for a certain time to the action of each ray, he observed sensible effects, though with an intensity continually decreasing in the indigo and blue rays. Hence they considered it as extremely probable, that if he had been able to employ agents still more sensible, he would have observed analogous effects. To show clearly the great disproportion which exists in this respect between the energies of different coloured rays, M. Berard concentrated, by means of a lens, all that part of a spectrum which extends from the green to the extreme violet; he also concentrated, by means of another lens, all that portion which extends from the green to the extremity of the red. This last pencil formed a white so brilliant that the eyes were scarcely able to endure it; yet the muriate of silver remained exposed more than two hours to this brilliant point of light without undergoing any sensible alteration. On the other hand, when exposed to the other rays, which were much less bright and less hot, it was blackened in less than six minutes.

After some further remarks on the importance of M. Berard's experiments, they proceed as follows:—"If we consider solar light as composed of three distinct substances, one of which occasions *light*, another *heat*, and the third *chemical combinations*, it will follow that each of these substances is separable by the prism into an infinity of different modifications like light itself; since we find by experiment, that each of these properties is spread, though unequally, over a certain extent of the spectrum; and we must suppose, on that hypothesis, that there exist *three spectrums* one above the other; namely, a calorific, a colorific, and a chemical spectrum. We must likewise admit that each of the substances which compose the three spectrums, and even each molecule of unequal refrangibility which constitutes these substances, is endowed, like the molecules of visible light, with the property of being polarized by reflection, and of escaping from reflection in the same positions as the luminous molecules."

From that time numerous experiments were conducted by several eminent researchers, including the discovery of the more celebrated MM. Niepce and Daguerre.

Daguerre and Niepce's Discovery.—To the inventive genius of these gentlemen we are indebted for the first practical application of this great discovery; but, like most great conceptions of the human mind, this art, as we have seen, advanced by slow steps, and was indicated from time to time by the isolated facts we have briefly alluded to.

The researches of M. Niepce were commenced in 1814, but it was not till 1826 that he was made aware, by the indiscretion of an optician employed by both, that M. Daguerre was pursuing the same course of experiments. A correspondence between the two philosophers was the result, and henceforth their researches were pursued in common; and some years later resulted in the discovery of this branch of the art since known as the Daguerreotype. In 1833, M. Niepce died, having communicated all his discoveries to M. Daguerre, and, in 1839, that gentleman, with a most laudable abnegation of self, communicated his discoveries to the public.

Fox Talbot's Discovery.—About the same time Mr. Fox Talbot, stimulated, no doubt, by the patriotic example of M. Daguerre, published the calotype process, thus giving birth to a new branch of the art.

That gentleman, it appears, had been carrying on his experiments for five years previously, in perfect ignorance of what Daguerre and others were doing, and had aimed at a method by which the sensitiveness of the salts of silver was increased to a marvellous degree. I cannot do better than give an extract from his own communication.

After saying how marvellous it seems that, in a few minutes, a picture is produced, displaying the thousand florets of an Agrostis, with all its capillary branchlets, and so accurately delineated, that not one is without its little bivalve calyx, requiring to be examined through a lens, he proceeds:—

"And, again, to give some more definite idea of the rapidity of the process, I will state that, after various trials, the nearest valuation which I could make of the time necessary for obtaining the picture of an object, so as to have pretty distinct outlines when I employed the full sunshine, was half a second." He was then speaking of the paper used in the solar microscope.

Mr. Fox Talbot also published an account of his first *photogenic* experiments (for this term was first introduced by that gentleman), and I shall again make use of extracts from it, as they will better convey an idea of his discoveries and their importance than any words of mine:—

"In order to make what may be called ordinary photogenic paper," he says, "I select paper of a good firm quality and smooth surface. I do not know that anything answers better than superfine writing-paper. I dip it into a weak solution of common salt, and wipe it dry, by which the salt is uniformly distributed throughout its substance. I then spread a solution of nitrate of silver on one surface only, and dry it at the fire. The solution should not be saturated, but six or eight times diluted with water. When dry, the paper is fit for use.

"I have found, by experiment, that there is a certain proportion between the quantity of salt and that of the solution of silver which answers best, and gives the maximum effect. If the strength of the salt is augmented beyond this point, the effect diminishes, and, in certain cases, becomes exceedingly small.

"This paper, if properly made, is useful for all photogenic purposes. For example, nothing can be more perfect than the images it gives of leaves and flowers, especially with a summer sun,—the light, passing through the leaves, delineates every ramification of their nerves.

"Now, suppose we take a sheet of paper thus prepared, and wash it with a *saturated* solution of salt, and then dry it. We shall find (especially if the paper is kept some weeks before the trial is made) that its sensibility is greatly diminished, and, in some cases, seems quite extinct. But if it is again washed with a liberal quantity of the solution of silver, it becomes again sensible to the light, and even more so than it was at first. In this way, by alternately washing the paper with salt and silver, and drying it between times, I have succeeded in increasing its sensibility to the degree that is requisite for receiving the images of the camera obscura.

"In conducting this operation, it will be found that the results are sometimes more and sometimes less satisfactory, in consequence of small and accidental variations in the proportions employed. It happens sometimes that the chloride of silver is disposed to darken of itself without any exposure to light; this shows that the attempt to give it sensibility has been carried too far. The object is to *approach*, as near as possible, to this condition, without *reaching* it, so that the substance may be in a state ready to yield to the slightest extraneous force, such as the feeble impact of the violet rays when much attenuated. Having, therefore, prepared a number of sheets of paper with chemical proportions slightly different from one another, let a piece be cut from each, and, having been duly marked or numbered, let them be placed, side by side, in a very weak diffused light for a quarter of an hour. Then, if any one of them, as frequently happens, exhibits a marked advantage over its competitors, I select the paper which bears the corresponding number to be placed in the camera obscura."

CHEMISTRY OF PHOTOGRAPHY.

General Remarks.—The wonderful discoveries announced by M. Daguerre and Niepce, and Mr. Fox Talbot, produced a host of followers, who have brought them to the highest perfection. M. Claudet, one of the earliest, discovered a mode of taking objects by subjecting the plate to vapour of chloride of iodine. Messrs. Fizeau, Caudin, and Leon Foucault, by the aid of divers preparations of bromine, obtained impressions with great rapidity; and, in 1840, M. Fizeau succeeded in fixing the image by means of chloride of gold.

Having thus introduced the subject in the words of the respective authors, and given a brief history of subsequent discoveries, I shall now, previous to going into the manipulating branches of the science, devote some little space to the chemical agents which we shall use, and recommend the reader to make himself as much acquainted with their nature and photographic properties as possible; for I can assure him that if he does not do so, the time spent on the study of the science will be almost thrown away.

The first of the photographic chemicals which will come under our notice, taking them alphabetically, will be—

Acetic Acid.—The strongest acetic acid, named "Glacial," and sometimes "concentrated acetic acid," from its property of becoming solid at low temperatures, contains only about one-sixtieth of its bulk of water. The crystals melt, at about 50°, into a pungent limpid liquid, with a smell resembling strong vinegar, of which, in fact, it is the base; the distilled vinegar of the shops being acetic acid diluted with from 5 to 7 parts of water. It is often contaminated with a trace of sulphuric acid, which may be detected by the addition of a little chloride of barium, when, if any sulphuric acid be present, we obtain a white precipitate.

Acetic acid is of the greatest use in all the photographic processes which require development, as it governs or checks the action of pyrogallic and gallic acids, and the sulphate of iron on the salts of silver undergoing decomposition; it preserves the whites or parts of the picture not acted on by light; it also keeps the picture clean by preventing any decomposition, except that caused by the light. I may add, that tartaric and formic acids are sometimes used for the same purpose, but I am inclined to give the preference to the acetic acid.

Acetic acid is also the best acid for correcting the alkalinity of the nitrate of silver bath, which will be explained at length as we proceed.

Albumen, or white of egg, is very much used in preparing the surface of paper for positive printing. It is thoroughly beaten up with water and salt, the action of the nitrate of silver partly coagulates the albumen, and in turn is converted into chloride of sodium by an excess of nitrate of silver—a combination extremely favourable to the production of a picture by the action of light. Albumen, containing small quantities of sulphur and phosphorus, gradually discolours the solution of nitrate of silver used for exciting or making sensitive. This discolouration may be easily removed by scraping some pipe-clay into the solution, stirring it up, and allowing it to remain for a day or two, and then filtering carefully. Albumen cannot be used with ammonia nitrate of silver, as the alkaline action of the ammonia would prevent coagulation in the albumen, and cause its separation from the paper.

Alcohol.—Alcohol must not be confounded with "spirits of wine," as the latter contains a considerable quantity of water, which would prove almost fatal to the collodion process, causing a precipitate of the cotton and a separation from the ether: a proof of this may be seen at once n a collodion picture that has been taken with a collodion containing much water in the alcohol. Upon drying it, and viewing it by transmitted light, you will at once perceive that it has a *grain* something similar to *fine muslin*, so that it is of the greatest consequence to obtain the alcohol as free from water as possible. To do so it will be best to mix quick lime, powdered, and alcohol together in equal weights, by distilling both together; the alcohol will come over pure, leaving the water with the lime, for which it has a great affinity.

Ammonia is, or ought to be, only used photographically for the purpose of making ammonia nitrate of silver; for which process see *Silver*. It should be kept in a stoppered bottle, as it rapidly absorbs carbonic acid from the air, which converts it into carbonate of ammonia.

Bichloride of Mercury, or corrosive sublimate, is a highly poisonous salt, very sparingly soluble in water, unless free hydrochloric acid be present. It is used for the purpose of improving glass pictures—of which more anon—and for removing the yellowness sometimes caused in the lights of a print, when the gold colouring bath is used.

Bromine.—This is a deep reddish-brown liquid, fuming strongly at common temperatures, and highly suffocating. It exists in sea-water combined with magnesium, and is closely analogous to chlorine and iodine, having stronger affinities than the latter and weaker than the former; that is to say, bromine would displace iodine, and chlorine would displace bromine. It is sparingly soluble in water, soluble in alcohol, more so in ether.

Bromide of Potassium is a mixture of bromine and caustic potash, heated to redness to drive off the oxygen from the *bromate* of potash, the latter becoming bromide of potassium on the loss of its oxygen. It is used for the formation of bromide of silver (see *Silver*).

Chlorine is a greenish-yellow gas, of a pungent and suffocating odour. As has been remarked, closely analogous to the other two of the group, bromine and iodine, the gas has a density of two and a half times heavier than air. It is found abundantly in nature in combination with sodium, in solution in sea-water and rock-salt; and is very useful in the arts for its bleaching properties. It has such a strong affinity for hydrogen that it absorbs it greedily, thus breaking up the structure of the organic substance, the latter being bleached by destroying its colour. It can be always discovered, either free or in combination, by a solution of nitrate of silver, with which it forms a white precipitate (chloride of silver).

Chloride of Sodium, or common table salt, is very useful to the photographer, as it bears the same relation to the positive printing that iodides and bromides do to the negative. Its sources are inexhaustible, being found in large quantities in the ocean as a solution, in the earth as a solid. It is a combination of chlorine and sodium. It fuses without decomposition at a dull red heat; but if the heat be pushed too far it sublimes, and the melted salt on cooling becomes a hard white concrete mass. It is sparingly soluble in weak alcohol, but nearly insoluble in absolute alcohol; it is soluble in three times its weight of water, and crystallizes in cubes which are anhydrous (without water). As chloride of sodium is often contaminated with chlorides of magnesium and calcium, also sulphate of soda, it is best if you can obtain it pure. You must do so by neutralizing hydrochloric acid (spirits of salt) by carbonate of soda. As has been already noticed, it is a very important salt in photography, being used most extensively in the preparation of positive-paper.

Chloride of Ammonia, or muriate of ammonia, is a soluble salt formed by the combination of chlorine and ammonia. It contains more chlorine than an equal weight of chloride of sodium, and may be used instead of that salt in the preparation of positive printing paper.

Chloride of Silver, formed by a combination of chlorine with a solution of nitrate of silver (see *Silver*).

Chloride of Gold.—Take three parts nitro-muriatic acid, put it into a cup, and drop a piece of pure gold into it one-third its weight; let it evaporate until chlorine vapour is disengaged, then let it crystallize. An impurity sometimes found in the iodide of potossium (which see).

Chloride of Potassium.—When there is much carbonate of potash in the iodide, it may be recognised by the crystals being very small and deliquescent (becoming moist when exposed to the air). The carbonate of potash is strongly alkaline to test-paper, and not very soluble in alcohol; indeed it is a question if it is at all soluble in absolute alcohol, but it is soluble in some degree in the weaker alcohols, to which it communicates an alkaline reaction.

The next impurity which comes under our notice is the sulphate of potash. This salt is decidedly not soluble in absolute alcohol, and the iodide of potassium may be freed from it by being dissolved in very strong alcohol. The presence of the sulphate of potash may be detected thus:—Make a solution of chloride of barium, and add a little to a solution of iodide of potassium; a slight milkiness need not be noticed, but if a decided white precipitate fall down, then you must either reject the iodide of potassium, or dissolve it in the strongest alcohol, when the sulphate being insoluble will remain undissolved.

We have now to consider the chloride of potassium. The presence of this salt is not so easily ascertained as either of the others; indeed it is rather difficult, and to discover an alkaline chloride in the iodide of potassium you must proceed thus:—Make a solution of the iodide suspected, and make a solution of nitrate of silver of the same strength, say twenty grains of each to one ounce of *distilled* water, mix and add to the iodide of silver a little liquor ammonia; if any chloride of silver (or chloride of potassium, which would form a chloride of silver) be present, it will dissolve in the ammonia, and after filtration may be precipitated by the addition of pure nitric acid; the iodide of silver must be well washed previous to the addition of the nitric acid, for as the latter often contains traces of chlorine, the presence of any free nitrate of silver, by combining with the chlorine on neutralizing, would very likely cause an error; it is of great importance that the iodide of potassium should be pure, as otherwise it may cause a great deal of trouble; it would not matter so much if the nature of the impurity were known, as in that case we could take steps to counteract its influence.

Cyanide of Potassium is a *highly poisonous* salt, formed by the combination of cyanogen gas and potassium. It generally contains a large per centage of potash, from which it may be freed by boiling in alcohol, which on cooling deposits it in crystals. It has a strong smell of prussic acid, and is freely soluble in water. It dissolves iodide of silver, and is used for that purpose in clearing away all the unaltered iodide of silver from the negative (a positive if on glass). It also removes the stains of nitrate of silver from the skin or linen. When using it on the fingers, be careful that it does not get into any cuts or sores, as it is almost as poisonous as prussic acid itself.

Ether is a highly volatile, inflammable spirit, obtained by distilling alcohol with sulphuric acid; the latter in its re-action removes one atom of water, and by so doing converts one atom of alcohol into one of ether. There are three kinds of ether sold in the shops—ordinary rectified ether, washed ether, and washed and re-rectified ether. Ether is a most important photographic chemical, being the solvent of "gun cotton," with which it forms collodion; and it is very necessary that it should be pure. It should not have an acid re-action with test-paper; it should not turn an alcoholic solution of iodide of potassium rapidly brown; it should not have a high specific gravity from too much alcohol or water; and it should be free from any smell of essential oils or of acetic ether. Provided ether be free from these defects, it matters very little which ether be used; if the ordinary rectified ether be pure, it will be the most economical. I shall treat this subject more fully when speaking of collodion.

Formic Acid is a fuming liquid with a pungent odour; it reduces the oxides of gold, silver, and mercury to the metallic state, and is itself oxidized into carbonic acid. The alkaline formiates possess the same properties. It is rather difficult to determine the strength of the commercial formic acid, it being always more or less dilute. It may be obtained in its full strength by distilling formiate of soda with sulphuric acid. It inflames the skin in the same manner as the sting of an ant, from which it gets its name, being originally discovered in the red ant (*formica rufa*), but is now prepared on a large scale by distilling *starch* with binoxide of manganese and sulphuric acid.

Gallic Acid.—This is obtained from gall-nuts, of which the best kind come from Turkey, being called "Aleppo galls." The galls are exposed, after being powdered, to the action of the air for a long time—five or six weeks. The mass must be kept moist during the operation by the addition of a little water from time to time. Thus the gallic acid is gradually formed from the *tannic acid* first produced, the gallic acid crystallizes in long, needle-like, silky crystals, having an astringent taste, taking about 100 times their weight of cold water to dissolve them; though, when boiling, three times will be enough. They can be easily purified and separated from the mass by boiling up in water, filtering the mixture while hot, and setting aside to cool; the gallic acid will crystallize on cooling. Gallic acid is but feebly acid, and is a very important agent inreducing the silver in the Talbotype process.

Although not strictly in its alphabetical order, I shall now introduce a substance of great importance, produced by the action of heat on the gallic acid.

Pyrogallic Acid.—At a temperature of about 410° Fah., gallic acid is decomposed, and a white sublimate forms, which condenses in lamellar-crystals. Unlike gallic acid, the new substance is exceedingly soluble in water, and is of the greatest importance in the development of collodion negatives, from the avidity with which it absorbs oxygen. Although termed an acid, it is perfectly neutral.

Gelatine.—This is an organic substance, obtained by boiling bones, horns, hoofs, calves' feet, or similar animal refuse, into a jelly, which, in the mass, is termed "*size*;" or, when dried and cut into slices, "*glue.*" *Isinglass* is a similar substance, obtained from the air-bladders of a species of sturgeon, and *heretofore* has been prepared chiefly in Russia.

Gelatine softens and swells in cold water, but scarcely dissolves until the water be heated; on cooling, it forms a tremulous jelly. An ounce of water will dissolve, when hot, about three grains without gelatinizing on cooling. It is somewhat analogous to albumen, but does not form any compound with the oxide of silver, as the latter does; hence its different action.

Gold.—*Chloride of Gold* when in solution is a bright yellow colour when diluted, but a deep red when concentrated. In the solid state it is a red deliquescent mass, without any apparent regular formation; and, although chemically neutral, it is acid to test-paper. Its chief use in photography is the property it possesses of blackening the shadows of a positive print, which it does to a wonderful extent. It is easily decomposed by sulphurous acid, charcoal, and many of the vegetable acids; also by protosulphate and protonitrate of iron. The addition of *ammonia* to perchloride of gold forms the dangerous compound "*fulminating gold.*" Hyposulphite of gold, or Sel d'Or, is a double hyposulphite of gold and soda, and is formed by the reaction of hyposulphite of soda on chloride of gold. It is very valuable in colouring positives on paper, and is very easily decomposed. It will be more fully noticed under the head of "The Colouring Bath."

Hydrochloric Acid is a volatile gas, exceedingly soluble in water, forming the hydrochloric or muriatic acid of commerce, which contains from thirty to forty per cent. of gas. It is used in the formation of chloride of gold, in combination with nitric acid, and for producing the yellow perchloride of iron.

Hydrosulphate of Ammonia is formed by passing sulphuretted hydrogen gas through ammonia. It is used for the purpose of separating silver from hyposulphite of soda, to darken negatives, and for testing solutions for silver, &c.

Hyposulphite of Soda, and the hyposulphates of gold and silver, will be fully described under the head, "The Colouring Bath."

Iodide of Potassium.—This salt, as the reader already knows, and I think there can be no objection to these facts being often repeated, is one of the salts chiefly used for the production of iodide of silver. Iodide of potassium is generally made by dissolving iodine in solution of potash until it acquires a slightly brown colour. This solution contains not only iodide of potassium, but *iodate of potash*, which may be got rid of by evaporation and heating the residue to redness, when the *iodate* parts with its oxygen and is converted into *iodide* of potassium.

Iodide of potassium has the following properties:—It forms white cubic and prismatic crystals, which should be hard, and scarcely, *if at all*, deliquescent; it is soluble in less than its own weight of water; alcohol will dissolve from two to eight grains to the drachm, according to its strength—the stronger the alcohol the less it will dissolve; *ether will not dissolve it at all.* Iodide of potassium as sold in the shops is nearly always slightly impure from the presence of carbonate and sulphate of potash.

Litmus Paper.—This is of the greatest use to the photographer, as it enables him to tell almost at once whether his solutions are acid or alkaline. It is made by soaking porous paper in a solution of litmus, digested in hot water; the paper when dry is quite blue, but in the presence of any acid becomes red, which changes back again to blue when brought in contact with an alkali; the red litmus paper is made by dipping the blue paper in water containing one or two drops of sulphuric acid to the pint. Litmus is a vegetable substance procured from various lichens which grow on rocks near the sea.

Protosulphate of Iron is the green copperas of commerce. It dissolves in about its own weight of water, and when in solution it is used as a developer for positives on glass; it improves by use and exposure to the air, and is extensively used by photographers.

Protonitrate of Iron.—This is another salt of iron, used for the development of positives on glass; but has nothing to recommend it for use in preference to the protosulphate.

Nitric Acid is much used in the preparation of pyroxyline, for which purpose it ought to be of the strongest possible description. It is often contaminated with chlorine or sulphuric acid; the presence of chlorine may be detected by diluting the acid with an equal bulk of *distilled water*, and then adding a few drops of nitrate of silver solution—a milkiness (chloride of silver in suspension) denotes the presence of chlorine. Sulphuric acid may be detected by the addition of a little chloride of barium, which, with the sulphuric acid, will form an insoluble precipitate of sulphate of baryta.

Nitrate of Potash, or saltpetre, is a very abundant natural product. It often contains a large proportion of chloride of potassium, which may be detected by dissolving a small portion, and adding a few drops of nitrate of silver; when, if the chloride of potassium be present, the never-failing chloride of silver will be formed.

Nitrate of Lead is made by dissolving the metal, or its oxide, in excess of nitric acid diluted with two parts of water. It forms, with sulphuric acid or soluble sulphates, an insoluble sulphate of lead.

Silver Solutions.—Silver and its different solutions are all-important to the photographist.

Nitrate of Silver.—Nitrate of silver, or, more correctly speaking, nitrate of the oxide of silver, is made by dissolving pure silver in nitric acid (aqua fortis), which parts with oxygen to the silver, forming an oxide of silver, and that in turn becomes dissolved by another portion of the nitric acid. Nitrate of silver crystallizes in white scales. When the solution has been boiled down nearly to dryness, the crystals have a bitter metallic taste, and are very soluble in water, which will dissolve about its own weight. The nitrate used for photographic purposes should be dissolved in distilled water and re-crystallized, so as to be deprived of all traces of the nitric acid. A solution of nitrate of silver in distilled water is scarcely, if at all, affected by light, unless it be brought in contact with organic matter, when it becomes speedily decomposed, and thus it becomes so useful in photography; for if we wash a sheet of paper over with a solution of the nitrate of silver, and place on its surface any opaque figure, such as a coin, a leaf of a tree, or, what is better, a piece of black network, pressed to the surface by a sheet of glass, we shall, by exposure to the rays of the sun for a few minutes, obtain a correct copy of the figure; but with reversed effects, the parts uncovered being black, the parts covered remaining white. We thus form what we call a negative picture; for example—If we take three letters cut out of cardboard (Fig. 1), and place them on a piece of paper washed with a solution of nitrate of silver, press them close by means of a sheet of glass, and expose it to the sun's rays for five or six minutes, we shall obtain a picture similar to Fig. 2, and this also is the process by which the portrait at the head of this Treatise was obtained by a very able

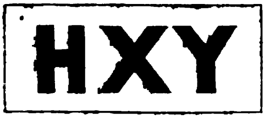


Fig. 1.

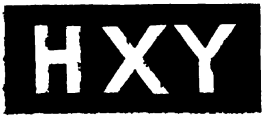


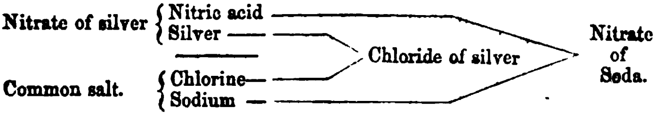
Fig. 2.

experimentalist. The negative was obtained by the usual Talbotype process, and the positive by placing the negative upon the prepared wood.

Now it is very obvious that, by removing the nitrate of silver from the white parts of the paper, and thus protecting them from any further action of light, we can, by repeating the experiment and using the negative just obtained, instead of the card-board letters, obtain a perfect copy of the latter. This is the principle of photographic reproduction—Having once produced a negative, whether in the camera or by contact, the number of copies that may be obtained from it are almost without limit.

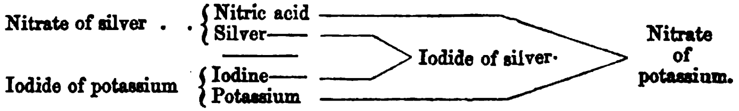
Nitrate of silver, when melted in a crucible, and cast into moulds giving it a shape resembling pieces of pipe stems, becomes the *lunar caustic* used in surgery; but this is scarcely pure enough for photographic purposes. It will be always better for the amateur to procure the white re-crystallized nitrate. If the nitrate obtained from the chemist or otherwise exhibit traces of nitric acid, the latter may be got rid of by heating the crystals carefully to some few degrees above boiling water for a short time. This must be done in a glass or porcelain vessel, as almost every metal has the property of decomposing the nitrate. So loosely is it combined with the oxygen that even light, as I have already shown, reduces it. If you take a solution of nitrate of silver, no matter what is the strength, and immerse in it a clean strip of copper, brass, iron, zinc, tin, or any other of the base metals, you will at once see that an action commences, the silver being thrown down as a metallic powder, and the other metal becomes dissolved; in other words, the silver has so slight an affinity (or liking) for oxygen, that the slightest force is able to separate them. This gives us another reason why silver is so very useful in photography.

Salts of Silver.—We can very easily obtain a great many salts of silver by double decomposition. I shall explain the meaning of double decomposition by a simple experiment, and one also that is essentially photographic:—Take nitrate of silver, 30 grains; distilled, or boiled rain water, 1 ounce (when the nitrate is dissolved take in another measure); common salt (chloride of sodium), 10 grains; water, not necessary to be distilled, 1 ounce. Now, if we pour the common salt solution into the silver one, we obtain directly a white curdy precipitate, perfectly insoluble even in boiling water or nitric acid. This is chloride of silver, or a mixture of metallic silver and chlorine. The double decomposition takes place thus:—



The chlorine, having a strong affinity for the silver, joins it; and the nitric acid being set free, very good-humouredly goes over to the sodium. We thus obtain one of the most important salts used in photographic printing. Expose the white powder to the light after washing it several times in fresh water, an operation easily performed because of its insolubility; and you will observe that it darkens all over, and presently becomes black. But do not for a moment suppose that it has blackened all through. No; the smallest possible quantity of the surface only has been acted on, the thinnest possible layer only blackened; remove the upper surface in the slightest degree, and you will find the part underneath perfectly white. Bear this fact in mind, as I shall have to refer to it more fully on another occasion.

Iodide of Silver.—This is produced in a similar way to the chloride, with the exception that we here use iodide of potassium, which by double decomposition, as before, produces—



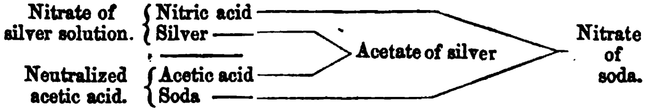
When the two solutions are mixed in the following proportions:—Nitrate of silver, 20 grains; distilled water, 1 ounce;—iodide of potassium, 20 grains; water, 1 ounce—a copious yellow precipitate is produced, which, like the chloride, is insoluble in water and nitric acid.

This salt, when perfectly pure, is not changed by the action of light; but if any excess of nitrate of silver be present, it becomes decomposed. The decomposition, in this case, has the property of proceeding onwards to blackness by the agency of the numerous developing solutions that we use, and that after the decomposition has once commenced. In this salt and the bromide of silver, being nearly alike in their nature, we observe the base of all the solutions for papers used in the camera.

Bromide of Silver.—This salt is produced in the same manner as the iodide, using bromide of potassium instead of the iodide. If you use any bromide or iodide, such as the iodide of tin, iron, zinc, mercury, cadmium, sodium, &c., you will obtain the same result, the oxygen going to the metal, the iodide or bromine going to the silver. In photographic experiments, however produced, the iodide of silver and the bromide of silver are always the same when in the solid or crystalline state.

The iodide of potassium, and the bromide also, have the power of dissolving the iodide or bromide of silver when added in sufficient quantities, a property of which we avail ourselves for the formation of iodized and brominized papers, to be explained more fully hereafter.

Acetate of Silver.—The acetate of silver will be found very useful in correcting a new nitrate of silver bath for collodion negatives, and may be made thus:—Neutralize one ounce of acetic acid by adding sufficient carbonate of soda, and add it to one ounce of distilled water, containing about 100 grains of nitrate of silver in solution. The action is thus represented:—



Hyposulphite of Silver.—This salt is formed by the action of hyposulphite of soda on nitrate of chloride of silver, and will be more fully treated under the head of Colouring Baths. It is very soluble in an excess of hyposulphite of soda, and its chief photographic use is in connection with that salt, to impart those rich brown or purple tints so much admired in finished photographs.

Ammonia Nitrate of Silver.—This is one of the most useful and important compound salts of silver; it is extensively used in printing, and may be made thus:—Dissolve in one ounce of distilled water fifty grains of nitrate of silver, and then add, drop by drop, liquor ammonia until the brown precipitate first formed is gradually redissolved; when filtered it should be put away in a dark bottle and kept from the light.

On the Means of Recovering Silver from Old Solutions.—This may be done in various ways. One of the most simple of the many is to insert a strip of clean zinc or copper in the solution of silver, and let it remain until the silver is all thrown down; but old hyposulphite of soda solution, containing silver, must be treated in a different manner.

To recover silver from the latter, it will be necessary to pass a stream of sulphuretted hydrogen through the solution, or to add a sufficient quantity of hydrosulphuret of ammonia to precipitate the silver, which will be thrown down as a sulphuret in either case. The first is the most troublesome, but by far the cheapest method.

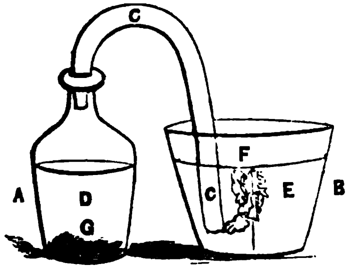


Fig. 3.

To make and pass the sulphuretted hydrogen gas you will proceed thus:—Get a large bottle, to which fit a piece of gutta percha tube bent thus (Fig. 3), which must fit in the neck or mouth of the bottle air tight, then put into the bottle about a quarter of a pound of sulphuret of iron, and about three-quarters of the contents of the bottle of water, to which has been added an eighth part of sulphuric acid (oil of vitriol), place the gutta-percha tube in its place, and the other end must go in the solution of hyposulphite of soda and silver, touching the bottom of the vessel; the sulphuretted hydrogen escaping up through the liquid decomposes its parts, and throws down the silver, the latter, as I have said, becoming a sulphuret of silver. A represents the bottle, B the vessel containing the hyposulphite-solution, C C the gutta-percha tube, D the solution of water and sulphuric acid, E the solution of hyposulphite of soda and silver, F the bubbles of sulphuretted hydrogen, and G the sulphuret of iron. The action must be continued until all the silver is thrown down, which may be ascertained by adding a little hydrosulphuret of ammonia, or by agitating the solution and smelling it; in the former case, if any silver remain there will be a black precipitate, and, in the latter, if the smell of the sulphuretted hydrogen be very strong from the liquid, it is a proof that all the silver has been thrown down. It may be as well to state here that the fumes, or gas, of the sulphuretted hydrogen is very poisonous when in a concentrated state, and, therefore, the operation should be carried on out of doors. The hyposulphite solution should be frequently stirred.

When all the silver is thrown down, it must be collected and washed on a filter by pouring water through it until the latter passes through quite clear, and will not give a precipitate with a few drops of nitrate of silver solution; the black mass remaining may now be boiled up with nitric acid one part, water two; when all the red fumes cease to be evolved, the solution is to be diluted with water and filtered to get rid of any insoluble matter, which principally consists of sulphur with perhaps a small portion of chloride of silver and sulphuret; if the nitric acid contains any trace of chlorine, or if the insoluble portion be large in quantity, you may heat it pretty strongly on a piece of iron plate to get rid of the sulphur, and dissolve the remaining portion in a strong solution of hyposulphite of soda, and add it to the colouring hypo-bath. The solution that has been passed through the filter will be a solution of silver in nitric acid, or nitrate of silver, but will not be pure enough for photographic use; it will be better to convert it into chloride of silver by adding a solution of common salt, and washing the precipitate two or three times. The chloride, or sulphuret of silver may be converted to metallic silver by fusing it in a crucible with twice its weight of carbonate of potash, or a mixture of carbonate of potash and soda. When the heat has been carried on sufficiently, the whole flux may be poured out of the crucible, or the crucible and its contents may be allowed to cool, when the silver, a beautifully bright button, will be found at the bottom.

On the Means of Converting Chloride into Nitrate of Silver.—As we already know that nitric acid, even when boiling, will not act on the chloride of silver, we must go a little round to bring the two together, and the best method of obtaining that important result will be as follows:—After well washing the chloride, pour it out into a flat dish, in which place a bar of metallic zinc in contact with the chloride, a small quantity of oil of vitriol diluted with four parts of water is then added, until a slight effervescence is seen to take place. The dish must then be set aside for two or three days, and must not be disturbed in any manner. The reduction commences with the chloride immediately in contact with the zinc, and afterwards radiates in all directions. When the whole mass has become of a gray colour, the bar of zinc is to be carefully removed and the adhering silver washed off with a small stream of water. In order to insure the purity of the silver, a fresh addition of oil of vitriol must be made after the zinc has been removed, in order to dissolve any fragments of metallic zinc which may have become detached by accident, and after the digestion has been continued for a few hours, the gray powder is to be washed several times with water, until the water which runs off will not give a precipitate with carbonate of soda; it may then be converted into nitrate of silver by boiling with nitric acid one part, water two, and evaporated to crystals. The above formula is not so expensive or troublesome as the fusing with carbonate of potash. Bear in mind, that you must pour the oil of vitriol into the water, and the vessel in which they are mixed must be such as will *stand heat.*

Oxide of Silver is an olive brown powder obtained by adding potash to nitrate of silver. It is soluble in hyposulphite of soda, cyanide of potassium, ammonia, and nitrate of ammonia.

Sulphuric Acid, or oil of vitriol, is an acid possessing intense chemical powers, and readily displaces the greater number of acids from their salts; it clears organic substances by depriving them of water, and converts alcohol into ether by the same means, and is one of the elements used for the production of gun-cotton. Its action in the latter case will be more fully explained further on.

Tetrathionic Acid.—(See "Colouring Bath.")

ON THE OPTICS OF PHOTOGRAPHY.

Action of Light.—Having, for the present, finished the necessary remarks on Photographic Chemistry, I shall proceed to explain the optical and actinical (or chemical *decomposing* ray power) action of light on surfaces prepared photographically; and I may remark, *en passant*, that, but for our knowledge of the chemical action of light through glass, all our chemical knowledge of the theory of photography would be perfectly useless; we could no more obtain a perfect copy of a tree, a house, or a hay-stack, than we could fly—this being another proof, if such be necessary, of how dependent one branch of science is on another.

Light, the agent by which we are enabled to depict nature or art with an accuracy that baffles the most experienced artist, is derived from the sun. True it is that there are other sources of light; but at present we have nothing to do with them—we must confine our attention to solar light, and the chemical change it produces. This glorious light, which

> "Was given to quicken slumbering nature,
> And lead the seasons' slow vicissitudes
> Over the fertile breast of mother earth,"

now pours forth its beams, and in a sense not dreamed of by the poet, dispenses

> "Life and light on every side;
> Brightening the mountain cataract, dimly spied."

And yet how little do we know of the nature of a sunbeam. A solar beam of light is a bundle of rays, a ray being the smallest portion of light which can emanate from a luminous body. Each of these rays possesses distinctive characters, both as regards their chemical functions and colours. Sir Isaac Newton proved that the white light emitted from the sun is not so simple as it appears, but is composed of vivid colours and tints which we may prove to our own satisfaction, by performing the beautiful experiment called "Newton's Analysis of Light," being a prism (Fig. 4), or triangular mass of glass, which is so contrived that it may be adjusted to any angle, or placed in any required position. The shutters of the room being closed, we may admit a ray of light either by boring a hole in the shutters or separating them a little.

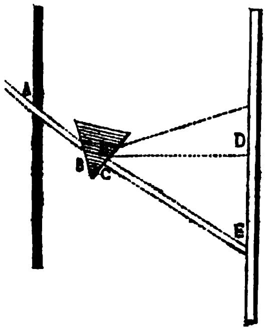


Fig. 4.

The ray of light A E (Fig. 4), being admitted into the darkened room by means of a hole A in the shutter. It will be seen that the space between the shutter and the spectator is traversed by the sunbeam or ray of light, which appears to cause little particles of dust to dance in the atmosphere of the room. This appearance, however is owing to the illuminating power of the sunbeam contrasting with the other darkened or non-illuminated space in the room, which renders the small particles of dust floating in the air visible. As soon as the prism B C (Fig. 4) is placed in the path of the sunbeam, so as to allow it to fall on one of its angles B, the ray will be refracted, or bent out of its course, so as to pass towards the back of the prism (as in the line D), and not in the same line A E that it would otherwise have done, had not the prism been interposed. Another effect also takes place: an elongated delicately-coloured image is formed upon the wall D E; and if you stand at a short distance from the prism you will see that these colours are spread out in a triangular form, the base of which is on the wall, and the apex, or point of origin, at the back C of the prism. Remove the prism, and it is seen that the splendid display of colours upon the wall has disappeared, and a round spot of white light E is seen below the place occupied by the solar spectrum.

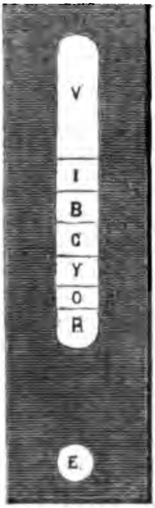


Fig. 5.

The coloured image upon the wall is called the ***prismatic*** or ***solar spectrum***, which, according to Sir Isaac Newton, is composed of seven different colours (Fig. 5). The colour at the lower portion of the image, or that nearest to the round white spot E on the wall when the prism was removed is of a red colour, and the one at the other end is of a violet colour; the whole intermediate parts being occupied by five other colours, and the whole arranged according to the table exhibited below, the proportion of each colour having been measured by Fraunhofer with the greatest care, with the results placed opposite to each corresponding with the 360 degrees of a circle, the red ray being the least, and the violet the most refracted of this chromatic image:—

Top.	
Violet	109
Indigo	47
Blue	48
Green	46
Yellow	27
Orange	27
Red	56
Bottom.	
	360

Since Newton's time, various experiments have been instituted and other rays detected; for instance, a crimson or extreme red ray has been discovered below the red ray, by examining the solar spectrum through a deep blue glass; and Sir John Herschel observed a lavender beyond the violet ray, by throwing the spectrum upon a piece of yellow paper. Mr. Stokes has also proved the existence of an extra spectral ray far beyond the violet; but, as we have remarked before, our consideration of light does not extend beyond its practical use to photographers.

Sir Isaac Newton was of opinion that white light was composed of seven primary rays, each possessed of a certain degree of refrangibility, or capability of being turned out of its natural course; and he also considered that the colour of a ray indicated its angle of refraction. Sir David Brewster has demonstrated that the seven primary colours, as Sir Isaac Newton called the rays of the solar spectrum, are not primary, but that only three of them are so—viz., blue, yellow, and red; the rest are compounds of the three primary colours, which form the spectrum by overlapping each other; and these are explained in the annexed diagram (Fig. 6).

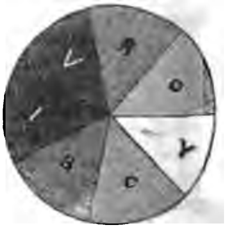


Fig. 6.

Such are a few of the phenomena relating to light regarded by the philosphers; its application to photography are as follows:—

Of the real nature of the rays, which form the sunbeam, little is known. The theory of Newton consisted in supposing the ray of light was produced by the emission of minute particles of matter travelling at an enormous velocity from a luminous body, and, when these minute particles impinged on any body, they were either thrown back, reflected, or absorbed, according to the surface on which they fell.

These particles entering the human eye, produce the sensation of light on the retina, which sensation is conveyed through the optic nerve to the brain.

The theory of the celebrated Huygens pre-supposes that the space beyond our atmosphere, and the interstices between the molecules, or ultimate atoms of all bodies, are filled with an imponderable ether, and that light is produced by the oscillation or vibration of this ether, which undulation is set up by some self-luminous body—of course, the sun.

Another theory may here be mentioned, although but very slenderly supported—namely, that set forth by Oersted, who considered that light was the effect of a rapid succession of minute electrical discharges taking place between a luminous body and the eye. Leaving these theories, however, to the philosopher, let us see how they affect the photographer.

The sunbeam—the ray of white light—contains powers within it of which the earlier philosophers had but a faint idea; besides its accompanying heat, there is a principle associated intimately with it, which has the power of decomposing and of determining the recomposition of chemical compounds. This principle has been already alluded to—it is "Actinism," and is as perfectly distinct in the nature of its properties. from light, as light is from the principle of heat, with which it is also closely connected.

Actinism may then be considered as the fundamental principle on which photography is based; and we would wish, before entering on a description of the various methods of obtaining sun pictures, to draw a broad distinction between light and actinism, more especially as many apparent difficulties present themselves, and seem almost insurmountable until tried by the principle we are about to lay down.

From what has been said, it will be supposed that what we consider light exerts a decided influence over certain chemical salts having a metallic base; but it now becomes necessary to show that light does no such thing—it is not *light*, but *a component part of light* which exerts this influence. In order to explain this seeming anomaly, let us consider the subject a little more carefully. A ray of white light consists of the three primitive colours—blue, yellow, and red; and their combinations forming, *en tablette*, the following:—Violet, indigo, blue, green, yellow, orange, red; these colours and shades being produced by the decomposition of white light by means of a prism. Of these shades, the *violet* has the greatest reducing or decomposing power. By this, I mean that the *violet* part of the decomposed portion of light exerts the most powerful influences on the unstable metallic salts, reducing them to their bases. This action is the *actinic* of the photographers; and the study of the action itself may be properly designated as *actinic-chemistry*. Every beam of light which we receive from the sun is composed of the three primary colours; these blending one with the other, form shades or *mixtures* of the three; thus we get four shades independent of the primitive colours, viz., indigo from blue and violet, green from blue and yellow, orange from yellow and red.

It may be asked, where does the violet come from? It is easily accounted for thus—if we decompose a single ray of white light, we get the following component parts by means of the prism:—

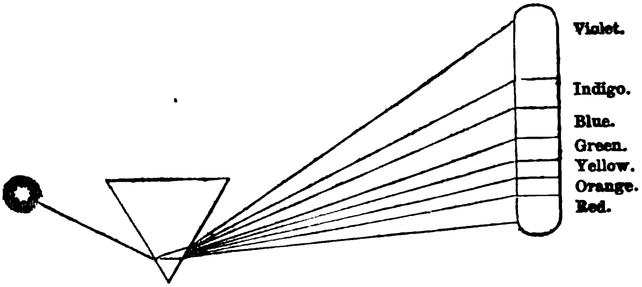


Fig. 7.

Now, if we decompose another ray, just below the above, we get the same parts reproduced, thus—violet comes first, or next the red, and is evidently produced by the mixture of red and blue (the next primary colour), or, more properly speaking, by the mixture of a deep red, which slightly extends lower than the red of the visual spectrum, with the indigo of the ray immediately above the under one; now this ray, or portion of a ray, has the power of more perfectly decomposing the unstable salts of silver than any other of the series; and, therefore, has acquired the term *actinic ray*.

The actinic power, and the light-giving power, may be more fully explained in the following diagram:—

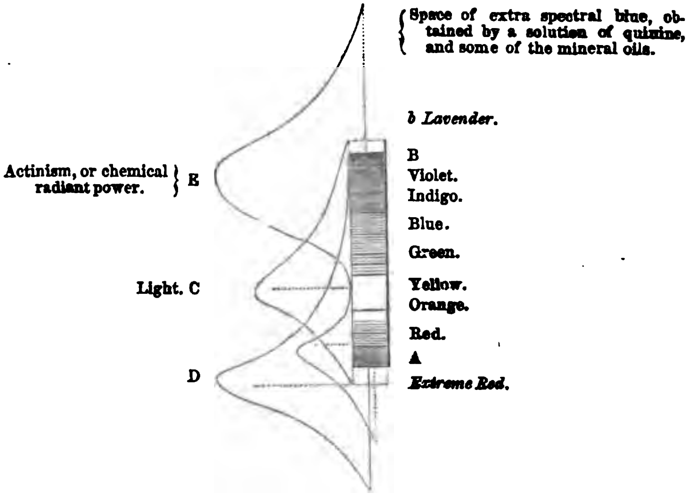

Space of extra spectral blue, obtained by a solution of quinine, and some of the mineral oils.
b Lavender.
B
Violet.
Indigo.
Blue.
Green.
Yellow.
Orange.
Red.
A
Extreme Red.
Actinism, or chemical radiant power. E
Light. C
D

Fig. 8.

In the above diagram, the greatest actinic, or chemical action, is shown opposite the violet ray E, and the least opposite the mixture of the yellow and orange C; below the red at A the actinic power becomes active again, because the extreme or deep red is about to pass into the violet with the indigo of the blue in the ray next below; at the same time, the part of the ray giving the brightest light is opposite the yellow and orange light C. We observe, also, that the point giving the greatest heat is just below the red D; but with that we have nothing to do. We thus ascertain that the chemical, or photographic action is confined, as already stated, to only a portion of the visual ray of light.

To speak more plainly, certain colours or shades act more powerfully than others, which can be proved by the following simple experiment:—Prepare a sheet of paper thus—float it on a weak solution of common salt, say ten grains to the ounce, and when dry, float it again on a solution of nitrate of silver, say thirty grains to the ounce. This must be done and the sheet dried while it is protected from white light. When dry, place on it three pieces of coloured glass, viz., red, yellow, and blue; expose the whole to the sun's rays for a short time, when it will be found that the paper has become rapidly discoloured under the blue glass, but remains unchanged under the red and yellow, although the last is by far the most transparent. This property of red or yellow colours of intercepting the actinic rays of light, we make the greatest use of in photography; but this subject will be treated of more fully under the head of "The Dark Chamber."

A ray of light is always more or less refracted or bent, depending on the density of the medium or substance through which it passes. The refractive power of some substances is immense, while that of others is very trifling, as the following table of some of the most important will show:—

Air	1·000294	Plate glass	1·542
Water	1·336	Flint glass	1·830
Alcohol	1·372	Do. containing much lead	2·028
Oil of cloves	1·535	Diamond	2·439
Crown glass	1·534		

A ray of light, passing through a vacuum, progresses in a perfectly straight line, and were it possible, under such conditions, to look at a brilliantly illuminated point, we should see it in its true position, viz., the numerous rays coming undisturbed directly to the eye. But all matter, however attenuated it may be, has the property of refracting or bending the ray of light; consequently we do not see the stars in their true position, owing to the refractive power of the atmosphere.

The law of refraction can be easily and decidedly demonstrated thus—take a basin, in the bottom of which place half-a-crown, or any other small bright substance, and removing a sufficient distance from it to lose sight of the coin, it will appear as in Fig. 9; A representing half-a-crown, and B the eye of the observer. The half-a-crown, of course, is invisible. Then request some person to pour water into the basin, taking care to keep your eye

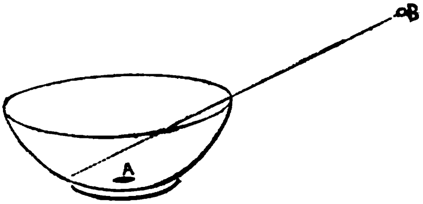


Fig. 9.

fixed on the same spot during the operation. The half-a-crown begins to appear, and gradually becomes more visible until it comes entirely into view. This fact is owing to the ray of sight (or light) being refracted, or beaten back, as in Fig. 10; C representing the water, and B A the ray of light refracted.

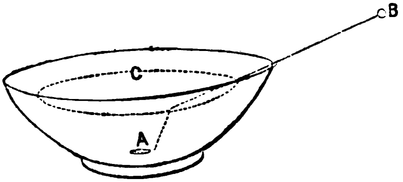


Fig. 10.

The explanation of this phenomenon is, that the ray of light producing vision in the eye is bent, on emerging from the water, and has all the effect of conveying our sight round a corner.

The refractive power of water is also observable when we thrust a straight stick or instrument into it, on aiming at any object. We see that the stick seems to be bent, and fails in reaching the point which we desired it should reach. On this account, the aim by a person not directly over a fish, must be made at a point apparently below it, otherwise the weapon will miss by flying too high. Persons who spear salmon in rivers require to calculate upon this refractive power in taking their aim.

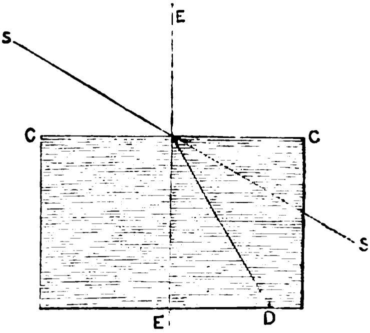


Fig. 11.

Another illustration of refraction is to allow a sunbeam S (Fig. 11), passing through a hole in the window-shutter of a dark room, to fall upon the surface of a fluid contained in a glass vessel, C C; instead of proceeding onward to D, it will be found to alter its course at the surface of the fluid, and pass along the line to D. Every substance has different refractive powers in virtue of its physical constitution; but a ray of light incident perpendicularly on a refracting medium, as the ray E (Fig. 11), suffers no refraction.

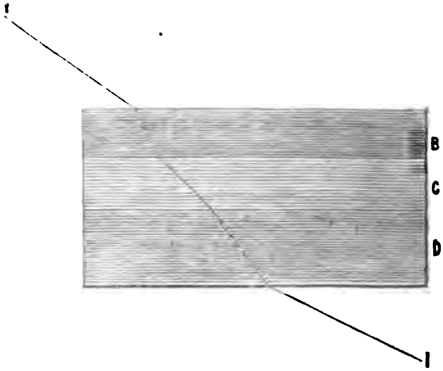


Fig. 12.

Again, if we float, one upon the other, fluids, B, C, D, having different powers of refraction, we shall then see the relative phenomena exhibited by the bending of the ray B B, as it passes through these different media, as represented in Fig. 12.

The mode of the refraction depends on the comparative density or rarity of the respective media. If the medium which the rays enter be denser, they move through it in a direction nearer to the perpendicular drawn to its surface. On the contrary, when light passes out of a denser into a rarer medium, it moves in a direction farther from the perpendicular. This refraction is greater or less—that is, the rays are more or less bent, or turned aside from their course—as the second medium through which they pass is more or less dense than the first. To prove this in a satisfactory manner, and at the risk of repetition, we make the following experiment:—Take an upright empty vessel into a darkened room, which admits but a single beam of light obliquely through a hole in a window shutter. Let the empty vessel stand on the floor, a few feet in advance of the window which admits the light, and let it be so arranged that, as the beam of light descends towards the floor, it just passes over the top of the side of the vessel next the window, and strikes the bottom on the side farthest from the window. Let the spot where it falls be marked. Now, on filling the vessel with water, the ray, instead of striking the original spot, will fall considerably nearer the side towards the window. And if we add a quantity of salt to the vessel of water, so as to form a dense solution, the point where the ray strikes the bottom will move still nearer to the window. In like manner, if we draw off the salt water, and supply its place with alcohol, the beam of light will be still more highly refracted; and oil will refract yet more than alcohol.

Our next care is to study the practical application of these laws of refraction to the manufacture of "lenses." By lens is meant what is commonly called a magnifying glass, which may be composed of any transparent substance; but in its application to photography it is generally made of glass as pure and colourless as can be procured, therefore we shall consider that a lens is a glass ground into such a form as to collect or disperse the rays of light which pass through it. These are of different shapes, and thence receive different names. The following figures individually represent sections of the variously-shaped lenses and other glasses used in optics. A is a triangular stalk of pure glass, of which we have here a cross sectional or end view, and which is called a prism. Each side of the prism is smooth. B is a section of a piece of plane glass, with sides parallel to each other. C is a sphere or ball of glass, and consequently is convex on all parts of its surface. D is a piece of glass convex or bulging on its two sides, and is called a double convex lens. It is this kind of lens which is used for magnifying objects, in spectacles, telescopes, and other instruments. E is a plano-convex lens, flat on one side and convex on the other. F is a double concave lens, or glass hollowed on each side. G is a plano-concave lens, or planed on one side and concave on the other. H is a meniscus, or lens convex on one side and concave on the other, both surfaces meeting, and of which we have an example in watch-glasses. I is an example of the concavo-convex lens, in which the surfaces disagree, or do not meet when continued. In all these lenses an imaginary line, re-

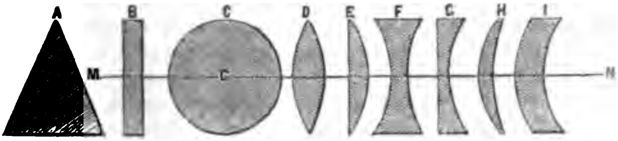


Fig. 13.

presented by M G N, and passing through the centres of the surfaces, is called the axis. Thus, the line said to pass through the centre of any lens, in a direction perpendicular to its surface, is called its axis.

The design in forming lenses is to procure a medium through which the rays of light from any object may pass, and converge to a corresponding point beyond. The manner in which the rays proceed through the glass, and then centre in a focal point, will depend on the form of the lens, its capacity for refraction, and the distance of the object.

If we take a piece of glass, flat on one side and cut into different faces on the other, and then look through it from the flat side at any object—for instance, a pea—we shall see as many peas as there are faces receiving rays from the single pea. We may exemplify this principle of multiplication by the annexed figure (Fig. 14), in which A B is a lens flat on one side, and cut into three faces on the other, G H. Y is the eye of the spectator, and P the pea to be looked at. The eye receives a pencil of rays direct through the lens at I, and sees the object without refraction. A pencil also proceeds from P to face G A, and another pencil proceeds from C to the face H B, and in both cases the rays are bent and refracted to the eye. This eye, however, does not recognise the path of either of these oblique rays, but perceives the image of a pea at D and at E; and thus three peas seem to be seen in place of only one.

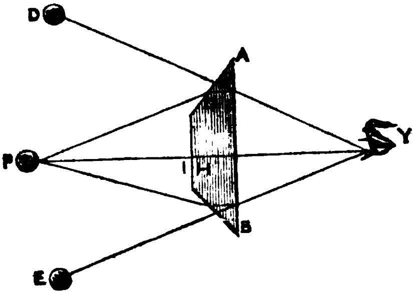


Fig. 14.

In smoothly ground lenses, in which there are no distinct faces to multiply the images of an object, the rays bend, as we have said, so as to meet in a corresponding point beyond them. A lens may consist of a perfect globe of glass, or globe filled with pure water, in which case the refractive power will be considerable. A double convex lens, which is the more common kind, may be viewed as a portion cut out of the side of a sphere, as seen in Fig. 15. Here, as in all cases of convexity, the focus of the parallel rays passing through the lens is at F, which is the centre of the sphere, of which the farther, or anterior side, is a portion, or a point at half the diameter of the sphere from it. (Half the diameter is technically called the *radius*.) Should we take a plano-convex lens, the focal point would be considerably different. In Fig. 16 we have an example of this kind of lens, which evidently possesses only half the refractive power of the double convex glass. Here the parallel rays, falling on the convex side of the lens, are seen to converge at the distance of the whole diameter of the sphere. Thus, the focal point at which the rays of light fall is always regulated by the degree of curvature of the lens. I shall illustrate this by various diagrams, and ask the reader's careful attention, for the subject is difficult, and cannot be comprehended by a superficial glance.

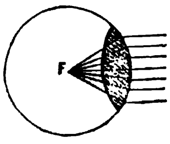


Fig. 15.

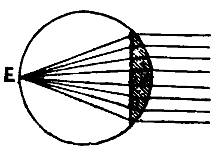


Fig. 16.

We take a double convex lens, represented by A B C (Fig. 17), the axis of which is the line G′ C D′. The ray D′ G′, being straight through the centre, suffers no refraction; but the rays D A and D″ B are refracted, so as to meet at the focal point G′. We now observe that the parallel rays E A, E′ C, and E″ B, and also F A, F′ C, and F″ B, falling obliquely on the lens, will, in a similar manner, be refracted, and have their foci at G and G″, at the same distance from the lens. Those lines which pass through the centre, as E′ C G″ and F′ C G, do not alter their direction, not being refracted. Thus, in whatever way parallel rays pass through a lens, we have a focal point beyond it, be it straight forward or in an oblique direction.

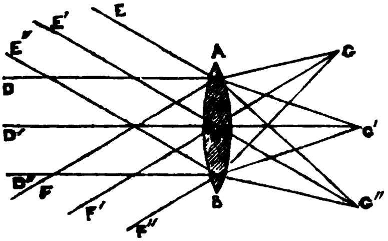


Fig. 17.

The distance at which the rays meet beyond the lens is exemplified in the next diagram (Fig. 18). Dr. Arnott, in his Treatise on Physics, says—"Rays falling from A on a comparatively flat or weak lens at L, might meet only at D, or even farther off, while, with a stronger or more convex lens, they might meet at C or at B. A lens weaker still might only destroy the divergence of the rays, without being able to give them any convergence, or to bend them enough to bring them to a point at all, and then they would proceed all parallel to each other, as seen at E and F; and if the lens were yet weaker, it might only destroy a part of the divergence, causing the rays from A to go to G and H, after passing through, instead of to, I and H, in their original direction.

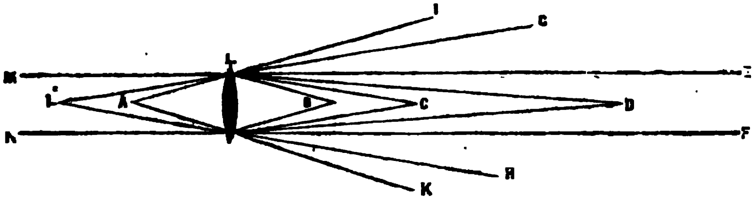


Fig. 18.

"In an analogous manner, light coming to the lens in the contrary direction from B C D, &c., might, according to the strength of the lens, be all made to come to a focus at A or at L, or in some more distant point; or the rays might become parallel, as M and N, and therefore never come to a focus, or they might remain divergent.

"It may be observed in the annexed figure, that the farther an object is from the lens, the less divergent are the rays darting from it towards the lens, or the more nearly do they approach to being parallel. If the distance of the radiant point be very great, they really are so nearly parallel that a very nice test is required to detect the non-accordance. Rays, for instance, coming to the earth from the sun, do not diverge the millionth of an inch in a thousand miles. Hence, when we wish to make experiments with parallel rays, we take those of the sun.

"Any two points so situated on the opposite sides of a lens, as that when either becomes the radiant point of light, the other is the focus of such light, are called conjugate foci. An object and its image formed by a lens, must always be in conjugate foci; and when the one is nearer the lens, the other will be in a certain proportion more distant.

"What is called the *principal* focus of a lens, and by the distance of which from the glass we compare or classify lenses among themselves, is the point at which the sun's rays—that is, parallel rays—are made to meet; and thus, by holding the glass in the sun, and noting at what distance behind it the little luminous spot or image of the sun is formed, we can ascertain the solar focus of a glass, as at A for the rays E and F."

From the preceding explanations it will be understood, that when an object is placed at any distance from a lens, an image of it will be formed in the corresponding conjugate focus; but to see this image distinctly, the eye must generally be placed at least six inches behind it, that is, farther from the lens. When, however, the object is placed in the principal focus, the rays are refracted parallel, and the image in this case is distinct when seen at any distance. But the most remarkable quality of a double convex lens remains to be noticed; we allude to its magnifying power. This quality is entirely a result of the refractive power of the glass; embraced within the sphere of the rays from the lens, the object is apparently expanded in size, and seems brought nearer to the eye. This may be elucidated, for small objects seen near, by a reference to the diagram (Fig. 19.)

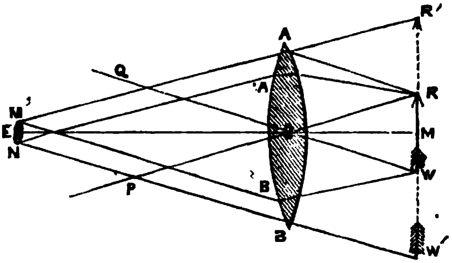


Fig. 19.

Let E be the eye, and M N the diameter of its pupil, R W a small object placed at the least distance of distinct vision (about six inches from the eye for small objects), and let R W be its apparent size when seen by the unaided eye. If a convex lens A B is now interposed between the eye and the object, so that the object R W shall be in the principal focus of the lens, an enlarged image R′ W′ of the arrow will then be seen, its extremities R′ W′ lying in the directions E A, E B. The directions of these rays are determined thus:—From R and W draw the central rays R C P, W C Q, through the centre C of the lens; then the rays of the conical pencil, proceeding from the point R to every point of the nearer surface of the lens, are refracted in such a manner by the lens, that they all emerge in directions parallel to the central ray R C P; but of the whole refracted pencil only a small portion enters the eye, namely, the pencil A M N A, limited by the size of the pupil M N; and the head A of the arrow, whence this pencil proceeds, appears to lie in the direction of the pencil E A R′ at R′. It is shown exactly in the same manner, that the point W will appear in the direction E B W′ at W′. The enlarged image of the small arrow R W is therefore R′ W′. The proportion in which the image is enlarged will be easily ascertained thus:—The triangles E R′ W′, C R W, are similar, and therefore the ratio of R′ W′ to R W, is that of E R′ to C R, or of E M to C M; that is, as the least distance E M of distinct vision, to the focal length C M of the lens. If, therefore, the least distance of distinct vision be divided by the focal length of the lens, the quotient will be its magnifying power. If E M be reckoned 6 inches for small objects, and if the focal length C M be 2 inches; then, since 6, divided by 2, gives 3 for a quotient, the magnifying power is 3 times. If C M were one quarter of an inch, then 6, divided by ¼, gives 24 for a quotient, and the magnifying power would in this case be 24 times.

A more simple explanation may be attempted as follows:—Turn to Fig 14, representing the lens with three faces on one side and flat on the other. There it is observed that the vision travels in the direction of the ray from the object, as it passes through the glass, and therefore sees an appearance of three objects. Now, in the above case of a magnifying lens, the vision in the same manner travels from the eye at E in the direction of the angle of refraction; it goes on to R′ and W′, and thus the actual object being drawn out, as it were, to meet these points of vision, or seemingly expanded by the bent rays, we of necessity see an apparently larger object. If the glass were cut in faces, instead of being smooth, the object would not appear drawn out, but would be multiplied in as many points as there are faces.

The inversion of the image by a lens may be illustrated by the diagram, (Fig. 20.) A B C is an arrow, with the point uppermost, placed beyond the focus at F, of a double convex glass *d e f*. In virtue of the refractive power of the lens, the rays which proceed at A meet at Z, and form an image of the arrow-point inverted; while the rays from C meet at X, and form a similarly inverted image of the feather part of the arrow. The rays proceeding from B unite at *b*. Here, only rays from A, B, and C are represented, for the sake of clearness; but, in point of fact, rays from all parts of the object proceed through the lens, and hence an entire image is formed in an inverted position. Should the object A B C be brought nearer the lens, the image will be removed to a greater distance, because then the rays are rendered more divergent, and cannot so soon be collected into corresponding points beyond. To procure a distinct image, the object must be removed farther than the focal point F from the glass. In this exemplification, the object seems to be diminished; but if we make the small arrow the object, the larger one will be the image of it magnified.

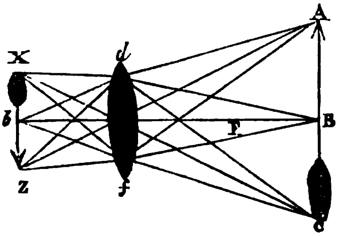


Fig. 20.

In order to explain the power of lenses in magnifying distant objects, and bringing them near us, let us suppose an object placed at one hundred feet distance from the eye of a spectator. Let us place a convex glass of twenty-five feet focal distance half way between the object and the eye; then, as has been previously observed, an inverted image of the object, and of the same size, will be formed fifty feet behind the lens. If this picture is looked at six or eight inches behind it, it will be very distinctly seen, and nearly as well as if the object itself had been brought to within six or eight inches of the eye of the spectator. If, however, instead of a lens of twenty-five feet focal length, a lens of a shorter focus is made use of, and so situated with respect to the eye and the object that its conjugate foci are at the distance of twenty and eighty feet from the lens—that is, the object is twenty feet before the lens, and its image eighty feet behind it—then the size of the image will be four times that of the object. If the eye, therefore, looks at this magnified image six inches behind it, it will be seen with great distinctness. In this case the image is magnified four times directly by the lens, and 200 times by being brought 200 times nearer the eye; so that its apparent magnitude is 800 times larger than before. At distances less than the preceding, the rule for finding the magnifying power of a lens, when the eye views the image which it forms at six inches distance, is, according to Sir David Brewster, as follows:—"From the distance between the image and object in feet, subtract the focal distance of the lens in feet, and divide the remainder by the same focal distance. By this quotient divide twice the distance of the object in feet, and the new quotient will be the magnifying power, or the number of times that the apparent magnitude of the object is increased. When the focal length of the lens is quite inconsiderable, compared with the distance of the object, as it is in most cases, the rule becomes this:—Divide the focal length of the lens by the distance at which the eye looks at the image; or, as the eye will generally look at it at the distance of six inches, in order to see it most distinctly, divide the focal length by six inches, or, what is the same thing, double the focal length in feet, and the result will be the magnifying power."

Having given the laws of optics sufficient notice, we shall next consider that portion which is more intimately connected with photography. One of the first objects to be considered in the manufacture of a lens for photographic purposes, is to produce one with the least *spherical aberration*. Now, if we take a double convex lens and produce the image of a figure (Fig. 21), we observe that the produced image is curved; and a little consideration will show that it is not possible that such a curved surface as that represented could produce an image of equal distinctness over every part of a plane surface: the rays cannot meet, as they are refracted from curved surfaces along any straight line; and supposing we receive on the surface of a lens a bright circular image, it will be brilliant and well defined around the centre, the light becoming fainter towards the edge, and at length passing into a cloudy halo, exhibiting the prismatic colours.

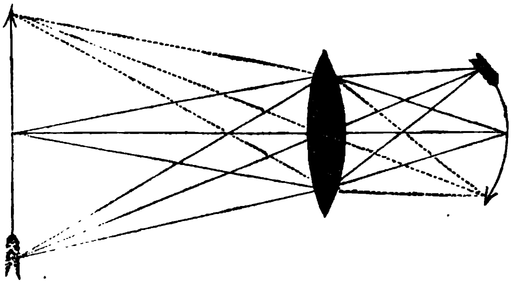


Fig. 21.

This is called *spherical aberration*, and to it is due that want of distinctness which commonly is found around the edges of pictures taken in the camera obscura.

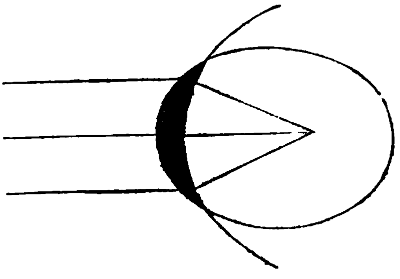


Fig. 22.

It is, therefore, important, in the selection of lenses, that we look for sharpness of definition over the whole of a perfectly flat field. But by attention to the two facts, that a lens, one surface of which is a section of an ellipse, and the other of a circle struck from the farthest of the two foci of that ellipse, as in Fig. 22, produces no aberration, much may be effected. A lens of this form, therefore, with a convex surface, part of an ellipsoid, the focal distance of which coincides with its farther focus, and a concave surface, part of a sphere, whose centre is that focus, will meet all our requirements. The mechanical difficulties of producing such lenses are great, but they may, by cautious manipulation, be to a great extent overcome.

If we take such a lens as we have been describing, and stop its centre with a blackened disc, leaving only a small portion of the edge for the light to pass through, and throw its image on a screen, we shall find it bordered with fringes of colour. At one distance red will prevail, at another violet. This is the result of chromatic aberration, and arises from the unequal refrangibility of the dissimilar rays. The red ray

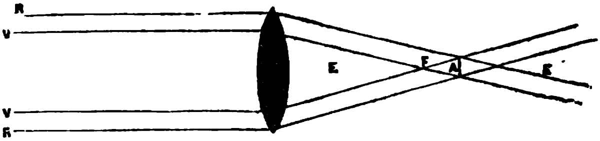


Fig. 23.

is less bent than the violet; consequently, supposing the rays R R (Fig. 23) to fall on the edge of a lens, they will converge to a point at F, whereas if the rays V V fall along the same circular line, they will, being more refracted, meet at F. Now if we place a disc at E, just the size of the cone of light, it will be edged with violet; but if we move it to A, the coloured border will be red.

By the table of the refractive powers of transparent bodies (page 119), it will be seen that, for a beam of white light, the difference between the most refractory flint glass and crown glass, in their refracting powers, is as 2·028 is to 1·534; and this proportion is maintained nearly, but not exactly, for all the coloured rays. If, therefore, we have a crown glass lens, the refractive power of which will place the focus at *a* for the violet rays, and at *b* for the red rays, and we grind to fit it a flint-glass lens, the refracting power of which would place the foci of the rays at *c*, *d* (Fig. 24),

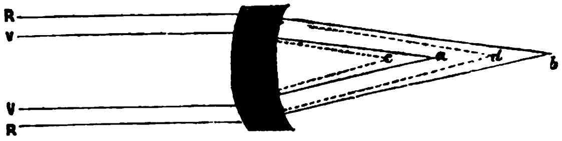


Fig. 24.

it will be seen that the result of such a combination would be the formation of a colourless image at a mean point between them, by *re-combining* the rays into white light; and such becomes the achromatic lens of the camera. In fact, to combine the violet and blue rays with the less refrangible red is all that is required; for this reason :—Suppose there be two prisms B F C and C D F, placed in juxtaposition and turned in contrary directions, as in Fig. 25. If we first assume these prisms to be of the same substance, the refracting angle C F D of the second being smaller than the refracting angle B C F of the first, the two prisms will produce the same effect as one prism B A F; that is, the white light which passes through them will not only be bent, but decomposed. But if the first prism B C F be made of crown glass, and the second of flint, we can destroy the dispersion, while preserving the refraction. The flint being more dispersive than the crown, and the dispersion produced by a prism diminishing with the angle of refraction in the prism, it follows that in suitably diminishing the angle of refraction C F D in the flint prism, with relation to the angle of refraction B C F in the crown prism, we can render the dispersive power of these two prisms equal; and as from their position the dispersion occurs in opposite directions, it is *compensated;* that is, the emergent rays E O are obviously reduced to a parallelism, and consequently give white light.

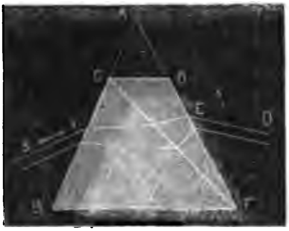


Fig. 25.

The relation of the angles B C F and C F D, however, which bring to a parallelism red and violet rays, not having the same effect on the intermediate colours, it follows that with two prisms we can in reality *achromatize* only two rays of the spectrum; so that, in order to obtain perfect achromatism, it would be necessary to have seven prisms, of substances unequally dispersive, and whose angles of refraction should be suitably determined.

So that one cause of rapidity in a lens is the perfection of the coincidence of the chemical and visual foci. Another cause, is the shortness of the focus. The greater length of focus possessed by a lens, the larger the picture produced, as a lens is generally calculated to cover, that is, have an uniform action over two-thirds its length of focus; or, to explain more fully, a lens of twelve inches focus will cover eight inches square, or nine by seven. It may seem strange that a lens that will cover nine by seven, could not cover nine by nine, but a little reflection will prove the contrary. Thus, if we draw a circle of the size properly covered by a twelve inch focused lens, and make a square, as represented by the solid lines (Fig. 26), we can observe that by taking an inch off one side we may add it to the other, or nearly so—the change being represented by the dotted lines— and that without going out of the circle; so that a lens of twelve inches focus covering eight square inches, would not be half as rapid as a lens of six inches focus, covering four square inches. The amount of light reflected from the same object being four times as much in one case as in the other. To copy an object requiring to be done quickly, we must therefore use *two large* lenses, placed some distance asunder, by which the length of focus is diminished and the rapidity is increased; the back lens catching the refracted rays of the front one, and refracting them still more. We thus obtain what is called a double lens, or more properly a double combination of lenses, as shown in Fig. 27.

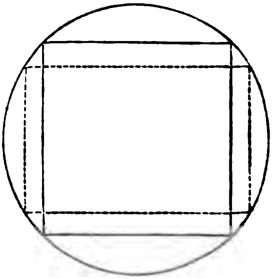


Fig. 26.

Combinations of Lenses.—These combinations can be obtained so as to take both portraits and views. The lenses for portraiture are arranged as represented in Fig. 27. If the lenses are removed from the cells, especial care must be taken to replace them in their former position, thus:—The flattest side of the lens B, the concave side of the inner lens A, and the least convex side of the outer lens A, must be turned towards the interior of the camera, and the ring of brass must be placed between the two lenses A so as to separate them. If views, pictures statuary, &c., are to be taken, the cell containing the lens A must be unscrewed and removed; the hood E and the cell containing the lens B must be unscrewed; the sliding tube holding the lens is now to be pulled out of the cell, and one of the circular plates of metal with a central aperture (called a stop) dropped into its place; the tube holding the lens is now reversed and pushed in so that the convex side of the lens is towards the interior of the camera, and the whole arrangement as represented by Fig. 28, where C is the sliding tube, B the lens, and D the stop. Three stops with different sized apertures belong to each set of lenses; but which is to be selected for use in any particular case, must depend on the judgment of the operator. In dull weather, and in copying objects indifferently illuminated, the largest size aperture stop is used; the middle size stop is for general use in moderate light, and the smallest size where the object to be copied is exposed to full sunshine or where great sharpness is required; it may be taken as a general rule, within certain limits, that the smaller the aperture which admits the light, the greater is the sharpness of the picture produced, but the time of exposure must be increased where such small apertures are employed.

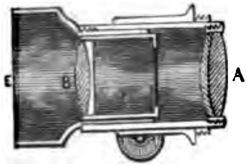


Fig. 27.

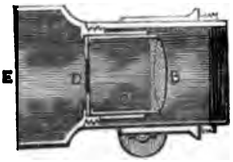


Fig. 28.

Claudet on Lenses.—The following observations on lenses by M. Claudet may not be out of place here:—"The question of the actinic focus is involved in another kind of mystery, which requires some attention. I have found that, with the same lenses, there exists a constant variation in the distance between the two foci. They are never in the same relation to each other; they are sometimes more or less separate; in some lights they are very distant, and in some others they are very near, and even coincide. For this reason I constantly try their position before I operate. I have not been able to discover the cause of that singular phenomenon, but I can state positively that it exists.

An optician, according to M. Lerebours' calculation, can at will, in the combination of the two glasses composing an achromatic lens, adapt such curvatures or angles in both that the visual focus shall coincide with the actinic focus; but he can obtain this result only for one length of focus. The moment the distance is altered the two foci separate, because the visual and actinic rays must be refracted at different angles in coming out of the lens, in order to meet at the focus given for one distance of the object. If the distance is altered, the focus becomes longer or shorter; and as the angle at which different rays are refracted remains nearly the same, they cannot meet at the new focus, and they form two images. If the visual and actinic rays were refracted parallel to each other, in coming out of the lens they would always coincide for every focus; but this is not the case. It seems, therefore, impossible that lenses can be constructed in which the two foci will agree for all the various distances, until we have discovered two kinds of glasses in which the densities or the refractive power will be in the same ratio as the dispersive power."

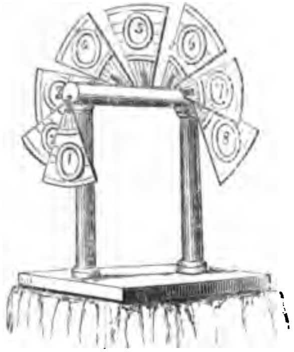


Fig. 29

Before concluding my present remarks on lenses, let me tell the reader that without a good lens he need not expect good pictures; and that economy in a lens produces twice the outlay in other ways. Let him not imagine, as many have—"Oh, I only want something to try with." He cannot come to a more false conclusion, as bad materials—bad lens especially—have been the cause of many a beginner never being anything else. I shall have to say something more about lenses hereafter, which will be more fully understood by the reader then than now.

Focimeters.—There is a neat little instrument made use of by most photographers for testing the lens they are about to use, and determining whether it works to focus or not; it is called the focimeter, and is the invention of M. Claudet. It is composed of fans placed at some little distance from each other, and numbered from 1 to 8. Supposing it is wished to try a lens, let the focus be tried upon say No. 4, and if that number prove to be the sharpest on the prepared plate or paper, the lens works to focus. If 2 or 3 should be sharper, then the lens must be pushed nearer to the ground glass, and the lens is not enough corrected. If, on the other hand, 5 or 6 should be sharpest, then the lens is over corrected, and must be drawn out a little more from the ground glass. There is one other quality to be looked for in a lens, and that is flatness of field. This can be easily ascertained at once by focusing on a window, when if you are using a 12-inch lens, and it gives an image of a window sash about 8 inches on the ground glass, you may be certain, if it show the bars perfectly straight, that it has a flat field, a property of the greatest importance in a good lens. Some amateurs reject a really good lens on account of air bubbles, but these are not in the slightest degree hurtful; one of the best lenses I ever saw had a dozen of them.

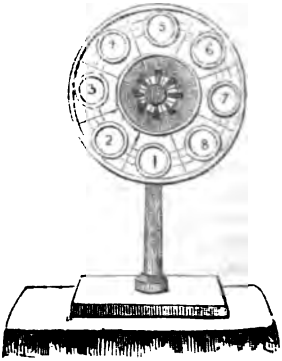


Fig. 30.

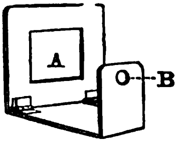


Fig. 31.

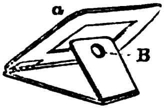


Fig. 32.

This focimeter was invented by the author for ascertaining the best condition for the camera, without the trouble of putting it up. It folds up so small as to go in the waistcoat pocket. The square A (Fig. 31) is cut out, and bears a proportion to the ground glass of the camera; by looking through the small hole B we see the view, as if it were framed (Fig. 32) the same in the act of being folded.

THE PHOTOGRAPHIC APPARATUS.

The first subject coming under our consideration, agreeable with the method I intend pursuing, that of making the reader acquainted with all the details and accessories before attempting to combine them, will be

The Camera Obscura, or Darkened Chamber.—This instrument was the invention of Baptista Porta, of Padua. Its principle will be best understood by the very simple experiment of darkening a room by closing the window-shutters, and admitting a pencil of light through a small hole in them. If a piece of paper is held at a little distance from this hole, the figures of external objects will be seen delineated upon it; and, by putting a small lens over the hole, they are rendered much more evident from the condensation of the rays by the spherical glass. This will be best understood by the following diagram (Fig. 33). Let C D be a window-shutter having a small aperture A, and E F a piece of paper placed in a dark chamber. Then, if an illuminated object, R G B, is placed on the outside of the shutter, we shall observe an inverted image of this object painted on the paper at *r g b*. In order to understand how this takes place, let us suppose the object R G B to have three distinct colours—red at R, green at G, and blue at B; then it is plain that the red light from R will pass in straight lines through the aperture A, and fall upon the paper E F at *r*. In like manner, the green from G, and the blue light from B, will severally fall upon the paper at *g* and *b*, and an inverted image *r g b* of the object R G B will be painted upon it, every coloured point in the object R G B having a coloured point corresponding with it on the piece of paper E F.

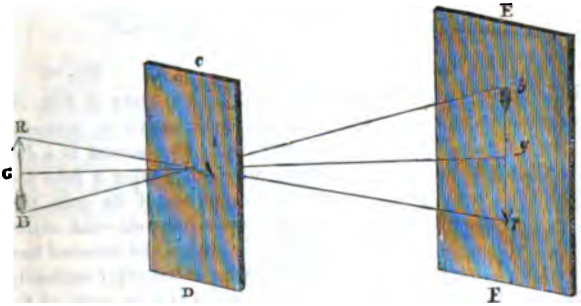


Fig. 33.

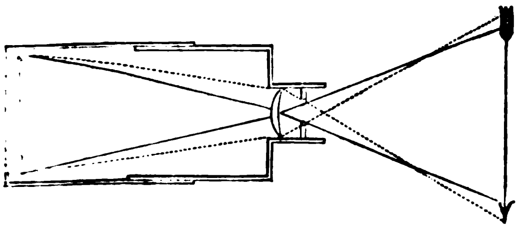


Fig. 34.

If, instead of a darkened room, we substitute a darkened box (Fig. 34), the same effect will be seen. Suppose, in the first place, the box to be without the lens, the rays would pass from the external arrow in nearly right lines through the opening, refracted only in passing the solid edges of the hole, and form an image on the back of the dark box. The lens refracts the rays, and a smaller but a more perfectly-defined picture is the result. This is the camera obscura.

Although highly appreciated for the magical pictures it produced, this instrument remained little more than a scientific toy until the discovery of MM. Daguerre and Niepce developed its powers. It is now so well known as scarcely to require description. The camera is a dark box with doors attached, having a tube for containing the lenses in one of its ends, through which the radiations from external objects pass, and form a diminished and reversed image upon the ground glass at the other extremity. The disposition of the various parts of this apparatus will be understood by reference to Figs. 35 and 36, where A represents the body of the camera; B, the lens; C, the ground glass focusing plate; and D, the dark slide, or back, for holding the prepared plate.

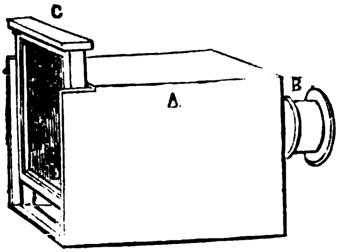


Fig. 35.

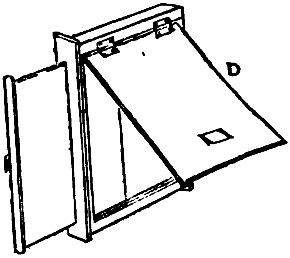


Fig. 36.

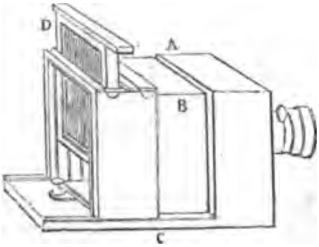


Fig. 37.

There are four grand distinctions in cameras, as to their structure, each being adapted to some peculiar branch of the photographic art; they have been named, from the nature of their configuration, Rigid, Sliding-body, Folding, and Semi-folding. The sliding-body camera will be found of most service in the glass operating room, from the capability it has of admitting a vast range of adjustment, which enables it to be used for almost every purpose. The peculiarities of this form of camera will at once become apparent by referring to Fig. 37, in which A represents the fixed body of the instrument, to which, at the front part, is fixed the lens; B is the second, or inner body, which slides along the board C, fastened to the fixed body; the groove for holding the focusing glass and the dark slide (Fig. 38) is in the hinder part of the sliding box, and is represented by the letter D. There is a slit in the bottom board, in which works the screw and button fastened to the moveable body, which allows of the latter being fixed after its proper position has been determined. From this description, it will be quite evident that a very long range of

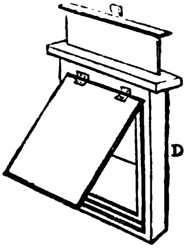


Fig. 38.

focus is obtained by this arrangement; and this will be found of the utmost convenience where we wish to obtain large portraits, or pictures small enough to mount as miniatures in a brooch.

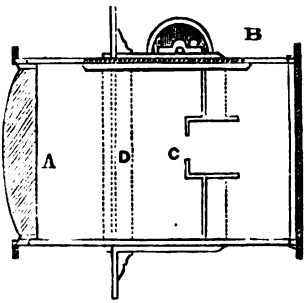


Fig. 39.

The great desideratum in a camera is perfect lenses. They should be achromatic, and the utmost transparency should be obtained; and, under the closest inspection of the glass, not the slightest wavy appearance should present itself, or dark spot be detected; at the same time, a curvature should be secured which prevents, as much as possible, all spherical aberration. The effect produced by this last defect is a convergence of perpendicularity: as, for instance, two towers of any building would be represented as leaning towards each other, or in a portrait the features would seem contracted, distorted, and mingled together, thus throwing the features out of drawing. A variety of moveable diaphragms or caps to cover the front aperture are useful, as the intensity of the light requires to be modified by them, and they should always accompany an instrument. A handy operator can always supply himself with these diaphragms. The engraving (Fig. 39) represents a section of a single lens; A, the lens; B, rack and pinion; C, the stop or diaphragm; D, sections of the camera.

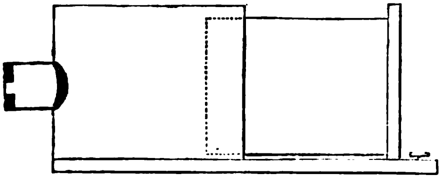


Fig. 40.

As in the phenomena of vision, so in the camera obscura, the image is produced by the radiations proceeding from the external object; and as these radiations progress from various parts, more or less illuminated, so are the high lights, the middle tints and shadows, most beautifully preserved in the spectral appearance. The colours also, being in the first instance the effect of some physical modification of the primary cause, are repeated under the same influence; and the definition, the colour, and soft gradation of light and shadow, are so perfect, that few more beautiful optical effects can be produced than those presented by the camera obscura.

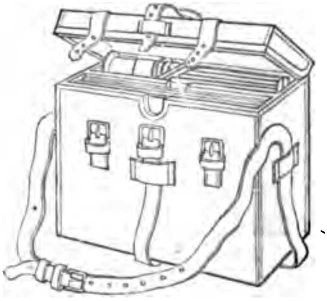


Fig. 41.

By a slight modification of the above simple box, we can form a camera in which we may expose a prepared sensitive plate or sheet of paper to the action of the rays which pass through the lens, the plate or paper being at the same time perfectly protected from the action of any other ray. Some cameras are very simple in construction, merely consisting of a single box, with the lens so mounted or fixed that it can be moved in or out to get the focus, which may be done by means of one tube sliding into another, or of one box having another sliding into it, the lens being fixed as in Fig. 40. The next form is the folding camera, invented by Mr. Ottewill, represented in Figs. 41, 42, and 43. In 41 it is represented packed as a knapsack, in 42 it is fully fixed, and in 43 half open. This is a very portable camera for travelling, and is kept steady and firm by the front board, which holds the lens, sliding into a groove made to hold it.

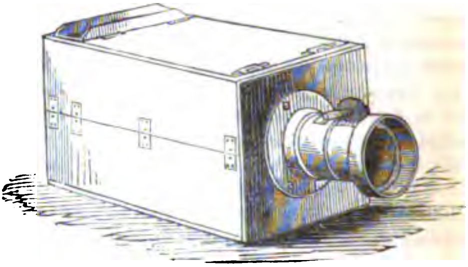


Fig. 42.

I shall next, with the reader's permission, introduce a camera which I invented and made for the late Major Halkett, of the 4th Light Dragoons, who was subsequently killed in the glorious charge at Balaklava. I shall only remark, that to the amateur who practices the paper processes it will prove very portable indeed. The form of this camera is that of a box when closed, in size about 13 inches long, 11 inches deep, and 6 inches wide, with a brass handle on the top by which to carry it (Fig. 44). A camera of the above dimensions will take pictures 11 × 8½ inches.

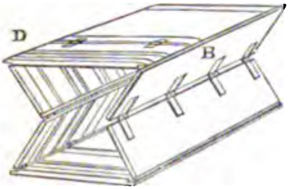


Fig. 43.

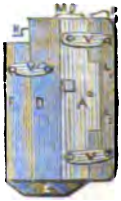


Fig. 44.

To shut up the camera, from Fig. 45, you first undo the supports R, which will let down the diaphragm, take out the screws G, G, G, open the air-hole Z, and shut H back into A; put the screws G, G, G in also, and place the two lids, L′ and L″, side by side on the front, and fasten them there by the two hooks V, V; then turn F up against D, and fasten it there by its own hook V. When you get home you take out the pressure-board, and inverting the paper frame, the paper holders will all fall back again out of the box F.

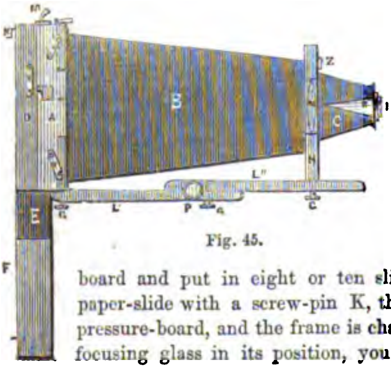


Fig. 45.

When the camera is opened for use, as in Fig. 45, take out the pressure-board and put in eight or ten slides with prepared paper, securing each paper-slide with a screw-pin K, through its eye T; you then replace the pressure-board, and the frame is charged with prepared paper. To place the focusing glass in its position, you lift the frame D about half an inch, and draw it back, when it will separate from A, as shown at Fig. 46, and make room for the focusing glass; having obtained a proper focus, you replace the frame D, pull up the sliding-shutter M, and the first sheet of paper is exposed; you shut down the shutter M, pull back the pressure-board a little, turn the first screw-pin back until you hear the paper-holder drop into the box F; you push in the pressure-board again, and paper No. 2 is ready to undergo the same process. The first paper-holder may be without an eye, as the pressure-board will keep it in its place until after exposure, and the pressure-board itself can hold another paper on its inside surface, thus increasing the number of pictures which may be taken during one excursion.

Explanation of Figures.—The light tint indicates brass, the middle tint wood, and the dark shading india-rubber material.

Brass. ▯
Wood. ▨
India-rubber. ■

Fig. 44. Side view, camera when closed.

Fig. 45. Side view, camera when open. A, frame of camera; B, body of ditto; C, cone also of india-rubber material, extended in front of the lens by three supports R; D, frame for prepared paper, each paper held in a separate holder (S, Fig. 49); E, communication between D and F, made of india-rubber material, through which the prepared paper in its holder passes into F, a box made to receive it after being exposed in the camera; G, G, G, nuts and screws used when the camera is open; H, upright frame for front of camera; I, diaphragm in front of lens; K, screw-pins to retain paper in frame until after exposure; L′ and L″, lids of camera; M, shutter in front of prepared paper;

Back view. Lateral view.
Fig. 46.

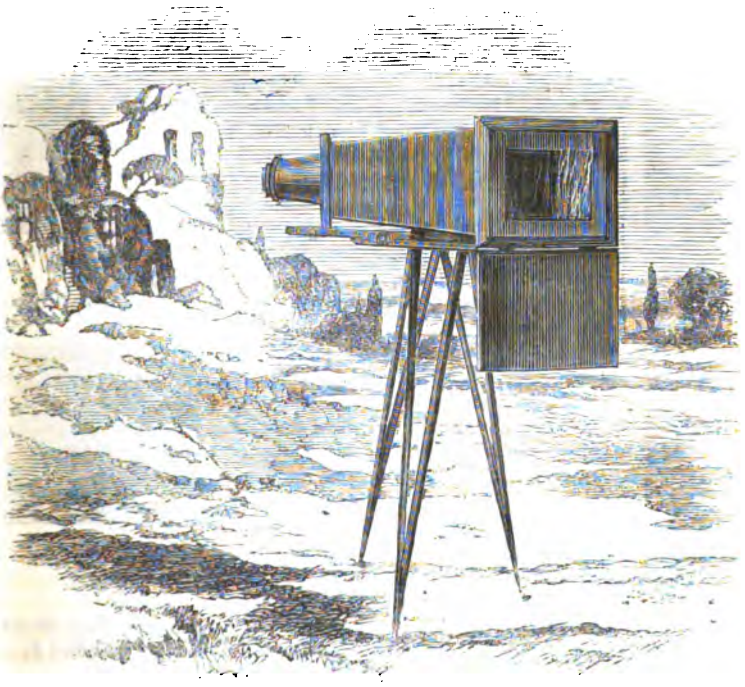


Fig. 47.—Major Halkett's Camera.

N, lens screwed into W from inside; P, rack and pinion adjustment for focusing; V, V, V, V, hooks and eyes.

Fig. 46. Diagram showing the way in which D is fastened to A.

Fig. 48. Front of camera. I, diaphragm; C, cone; H, frame; W, W, front plate of camera holding the lens; R, R, R, rests to support the diaphragm; Y, Y, plates to retain the front in its frame; X, graduated support to alter the horizontal line; Z, opening to allow passage to the air in opening and shutting the camera.

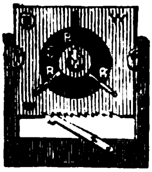


Fig. 48.

Fig. 49. Holder in which the paper is retained, made of mill-board; frame S, S, S, made of veneer, joins S at W, and doubles down on the dotted lines when the paper is in its place; T, an eye through which the screw-pin K passes.

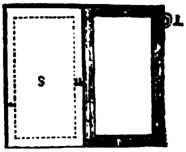


Fig. 49.

Fig. 50. Lid No. 1. A, A, the lid; B, plate by which it is screwed on the stand; C, guiding slit in plate; D*, hole by which that end is screwed to A (Fig. 45); F, F, guiding pins; X, X, focusing rack.

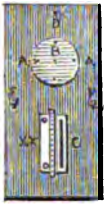


Fig. 50.

Fig. 51. Lid No. 2. A, A, the lid; B, slit for H (Fig. 45); C, C, guiding slits in plates; D, pinion; P, handle to ditto; E, groove for X, X, to work in; F, guiding pin; G, nut for screw in screwing the lids together.

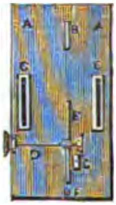


Fig. 51.

Fig. 52. Section of prepared paper frame. D, D, space occupied by paper slides; O, pressure-board to keep the paper against the sliding shutter.

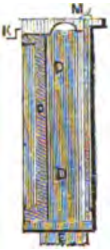


Fig. 52.

Fig. 53. End view of camera. O, pressure-board; K, K, K, screw-pins to retain the paper until after exposure.

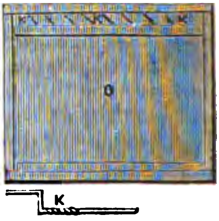


Fig. 53.

In fact, the forms of the camera are innumerable, and it matters little how they are made, provided that they are solid when working, and have a means of substituting the prepared plate or paper for the ground (or focusing) glass, and impervious to all light, except that which passes through the *lens*. When speaking of the collodion process, I intend to mention one or two other cameras, more particularly adapted to that process. A very portable camera is constructed by Vogtlander, the German optician, described as entirely made of brass, so that variations of climate do not affect it, and it occupies a very small space, when packed, even with all the materials for operating. The instrument known as the *copying* camera-box has an extra slide in the back end, by which it may be considerably lengthened at pleasure. We must not omit to mention that of M. Marten, which is known as the Panoramic Camera. The object of this invention is to reproduce, with an objective of medium dimensions, landscapes of great length, analogous to the panoramic feature.

Camera Stands.—The best constructed stands are made of maple or walnut wood, having a cast-iron or brass socket for receiving the camera, and having screws for elevating or depressing the instrument (Fig. 54).

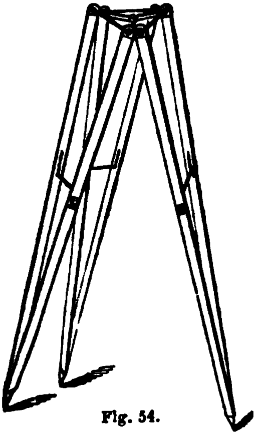


Fig. 54.

I shall next present my readers with a drawing of a dark frame for two pieces of paper and a glass, against which paper is pressed with a sheet of blotting-paper between. B B (Fig. 55), clips to fasten the frame when shut; *a a*, the slides or shutters.

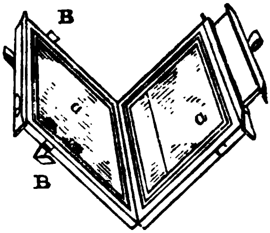


Fig. 55.

Figs. 56 and 57 represent two useful articles, namely, the nitrate and dipper, and the frame and rod for spreading solutions on paper. This consists of a piece of wood covered with soft flannel or blotting paper, on which the paper is laid, and B a glass rod, by means of which the solution is spread evenly over the surface of the paper.

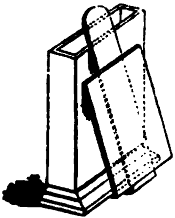


Fig. 56.

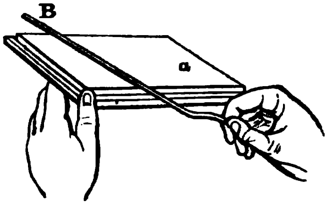


Fig. 57.

Our next figures represent as follows:—Fig. 58, a precipitating glass used for the purpose of making double iodide of silver. Fig. 59, a glass rod for spreading solutions on the paper; and Fig. 60, nippers for lifting paper out of the various solutions; while Fig. 61 and 62 represent a graduated drachm glass and a cup for pouring out the several liquids into their respective bottles.

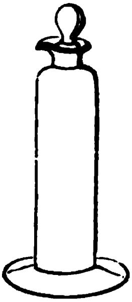


Fig. 58.

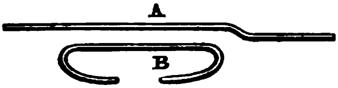


Fig. 59.

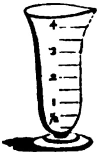


Fig. 61.

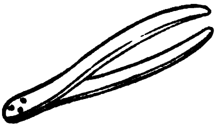


Fig. 60.

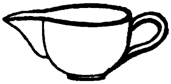


Fig. 62.

THE CALOTYPE PROCESS.

We have seen that the first person who discovered the preparation of a photographic paper, possessing such exquisite sensitiveness that it might be impressed with the image of a natural object in a minute or less in the camera, was Mr. Fox Talbot. He called this the calotype process; but some photographers, out of compliment to the discoverer, have since called it Talbotype, as the Daguerreotype is so called after Daguerre, who was the first to discover the properties of the process so named. M. Biot, a French chemist of great authority, who seems to have paid considerable attention to the subject, was called upon to report to the Académie des Sciences on the results of the new process. In his report he proceeds to say, after paying some attention to the Daguerreotype process:—

"It is scarcely expected that photogenic drawings, produced on paper, can at first equal the clearness and fineness of those obtained on level and polished metallic plates, because the texture of the paper, the roughness of its surface, the irregularity of its imbibitions, and the capillary communication established between the various unequally-marked parts of its surface, are so many obstacles to absolute strictness of delineation, as well as to the regular gradation of tints in the camera obscura; and the influence of these obstacles is greater when the chemical operation is slowly carried on. But where there is no pretence or necessity for submitting to the delicacies of art—when it is merely required, for example, to copy rare manuscripts faithfully—if we have papers which are very susceptible of receiving impressions in the camera obscura, they will suffice perfectly; particularly when they present, like those of Mr. Talbot, the facility of immediately procuring copies of the primitive drawing. It will, indeed, be found more commodious, and much more practicable, to put four or five hundred drawings in a portfolio, than to carry about a smaller provision of metallic plates with those indispensable squares of glass to protect them. Attempts are being made, at this time, to fix the images produced by the Daguerreotype—perfect prints, it is true, but which are as light as the vapour from which they are produced; and, indeed, to bring a voluminous collection of these fragile products through the accidents incident to long, and sometimes perilous voyages, is a task requiring no ordinary care. But whoever has attentively studied the combination of physical conditions whence these beautiful images result, will find it very difficult—I should not like to say impossible—to fix them without destroying, or at least without essentially altering, the causes which produce their charm; for the purposes, then, which I have mentioned, papers very susceptible of impression would still have the advantage of being less troublesome in removal from place to place, and much more easily preserved.

"Early in 1830, drawings on paper were handed about in the scientific circles of London and Paris, which were a great advance upon anything which had been previously done. These were the results of a new process discovered by Mr. Fox Talbot; but for several years after his process was made public, little or no progress was made in the art; and it is no injustice to Mr. Talbot to ascribe this interruption to the circumstance of that gentleman having protected his discovery by a patent. It is gratifying to be able to announce that Mr. Talbot has since made the country a free gift of his patents.

"The utility of sensitive papers for copying inscriptions was a natural consequence of the clearness of the copies of engravings which Mr. Talbot had already presented to the Academy. He has included, amongst others just sent, specimens of this special application of the art, which are copies of a Hebrew psalm, of a Persian gazette, and of an old Latin chart of the year 1279. Our brethren of the Académie des Belles Lettres, to whom I exhibited these impressions, were pleased to remark the fidelity of the characters, and their clearness, for they are rendered as legible as the original text. By this process, an old manuscript may be copied more quickly, and much more accurately, than by hand, even when the language in which it is written is understood.

"But this important extension will require much physical perfecting, towards which experimenters should direct their efforts. The first thing will be to increase the sensibility of the paper as much as possible, in order that the capillary communication of its various parts may not have sufficient time to deteriorate the effects of the local and immediate action of the light. I should be led to believe that to this kind of communication is principally to be attributed the fact remarked by Mr. Talbot, that, in experiments by application, it is more difficult to copy clearly a tissue of black lace spread on a white ground, than white lace on a black ground. But another more general and more hidden difficulty seems to me to proceed from the unequal faculty of various substances for reflecting the radiations which strike them, and perhaps from their aptitude for making them undergo physical modifications. For example, you wish to copy by radiation in the camera obscura a picture painted on canvas, wood, or porcelain: the different colouring substances employed by the painter are placed and distributed in such a manner that each of them absorbs certain portions of the total incidental light, and reflects especially towards your eye the complementary portions, wherein predominate the rays proper to form the tint of which it would give you the sensation. But the chemically active re-agent which the same parts of the picture receive and reflect is distinct from the light which affects your retina. In order that the chemical effect which it produces on the sensible paper, or on M. Daguerre's layer of iodine, may present, in light or in shade, the equivalent of the coloured parts, it is requisite—1st, that this reflected radiation be chemically active; 2nd, that the energy of its action be proportional to the intensity of illumination operated in the eye by the portion of luminous radiation reflected from the same point of the picture. Now this latter concordance certainly should not be fulfilled in an equal degree by the various colouring matters, which affect the eye in the same manner, and which the painter may substitute for one another in his work. Substances of the same tint may present, in the quantity or the nature of the invisible radiations which they reflect, as many diversities or diversities of the same order as substances of a different tint present relative to light; inversely they may be similar in their property of reflecting chemical radiations when they are dissimilar to the eye; so that the differences of tint which they presented in the picture made for the eye will disappear in the chemical picture, and will be confused in it in a shade, or of an uniform whiteness. These are the difficulties generally inherent in the formation of chemical pictures; and they show, I think, the illusion of the experimenters who hope to reconcile, not only the intensity, but the tints of the chemical impressions produced by radiations, with the colours of the objects from which these radiations emanate. However, the distant or near relations of these two species of phenomena are very curious to study, not only as regards the photogenic art, but likewise as regards experimental physics. I doubt not that examples of these peculiarities may be remarked in the images of natural objects and coloured pictures executed by the Daguerreotype; but very apparent ones may be seen among Mr. Talbot's present impressions. Thus, some of them represent white porcelain vases, coloured shells, a candlestick (of metal) with its taper, a stand of white hyacinths. The whole of these objects are felt and perceived very well in their chemical image; but the parts which reflect the purely white light, probably also the radiations of every kind, are, relatively to the others, in an exaggerated proportion of illumination, which, it seems to me, must result partially from the capillary communication during the continuance of the action; so that the inequality would be less if the paper were more sensitive or more rapidly acted on. In the hyacinth, the stalk and the green leaves have produced scarcely a faint trace of their configuration; but they are strongly defined, especially in the parts of the outline, where more or less perfect specular reflection takes place. The points of the candlestick (metallic) where this reflection occurred are copied by white stains locally applied, and which deteriorate the effect of the whole by their disproportion. But this is seen especially in a picture by Correggio, the frame of which was very vividly copied, whilst the figure on the canvas was hardly perceptible. This disproportion of lustre in the reproduction of some white parts, especially when they are dull and consequently very radiating, is sensible in certain parts of views taken by Mr. Talbot, to the point of rendering difficult the interpretation of the object to which they belong. However, these views are very satisfactory, as being obtained on paper, in the present season. Moreover, by an advantage peculiar to the chemical preparation which Mr. Talbot uses, it appears that the operations once completed, the drawings are no longer alterable by radiation, even acting with much energy.

"Indeed, we have here, as an example, four proofs of the same view of Mr. Talbot's house, with an identical disposition of lights and shades; so that some, at least, if not three out of four, must have been procured by superposition. Mr. Talbot is right in representing this property of reproduction as an especial advantage of his process, and it would indeed be very useful in voyages. I have exposed one of these drawings to the action of the sun—not very powerful, it is true—for several hours, and I have not perceived the slightest alteration in the lights. I think I understand that, in Mr. Talbot's opinion, the shades alone are strengthened under this influence. According to what I have just said, it should be expected that the triumph of this process, as of every other photogenic reproduction, would take place with objects of white and dull plaster. Indeed, Mr. Talbot's parcel contains eight copies of busts and statues; six of which chiefly, of various forms and sizes, present very remarkable results, especially taking into consideration the unfavourable season at which they were produced. There is not found in them the strict perfection of trace, nor the admirable gradations of lights and shades, which constitute the charm of M. Daguerre's impressions. But representations on sensitive papers must be considered as principally applicable to a different object, which does not impose such strict conditions of art, requiring only faithful images, sufficiently clear in their details to be readily recognised, and which, moreover, being obtained with rapidity, by an easy manipulation, may be kept with very little care, comprised in great number in a small compass, and moved from place to place with facility. Mr. Talbot's papers already present many of these essential qualities, with the advantage of being able to furnish numerous copies immediately. His efforts, and those of others occupied with the same subject, will conclude by adding to them everything which may be desirable, provided that expectation, or the pretension of a perfection of art physically incompatible with operations on paper, do not give a false direction to their endeavours. However, I may here add, that the height of success would consist in discovering a substance very susceptible of receiving impressions, which might be applied on a papyraceous leaf without penetrating deep into it, and which might, however, be fixed in it after the operation, as in Mr. Talbot's impressions. It does not seem necessary even that the first impression thus rapidly obtained should copy the lights and shades in their proper places, provided that its transparency and fixedness were such, that we might deduce them from the application of copies wherein the inversion would be corrected. And perhaps, by this decomposition of the problem into two successive operations, one of the best ways is opened by which it may be resolved."

"But so much improvement has taken place in the manufacture of paper for the purpose, as well as in the manipulation, that many of the early obstacles have been overcome; and photographs on paper, as may be seen at the present year's exhibition of the Photographic Society, have attained a degree of excellence not anticipated by the French savant. Paper has, moreover, qualities of its own for the purpose; it wants the glitter arising from the polished surface of the metal plate, so that its beauties can always be seen."

The Talbotype Process has been largely improved upon by Mr. Cundall and others; but it may be interesting to my readers to have the process described as practised by the inventor; adding, however, as I proceed, some of the more important improvements upon his formulæ.

The apparatus required are, two or three square shallow porcelain dishes, an ample supply of distilled water, a glass graduated measure and funnel (Fig. 63), a supply of blotting-paper, large flat and soft hair pencils, and a supply of the best writing paper of medium thickness, perfectly smooth surface, transparent, compact, and uniform in texture, and without speck, water mark, or maker's name. Also a supply of the following solutions, viz.:—

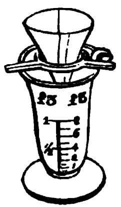


Fig. 63.

No. 1. A solution of 100 grains of nitrate of silver, dissolved in six ounces of distilled water.

No 2. A solution of 500 grains of the iodide of potassium in one pint of distilled water. (Mr. Cundall uses 400 grains iodide of potassium, and 100 grains of common salt, as an improvement analogous to that of M. Claudet in the Daguerreotype process.)

No. 3. A solution of 100 grains of nitrate of silver in two ounces of cold distilled water, adding to it a sixth part of its quantity of concentrated acetic acid.

No. 4. A solution of crystallized gallic acid, saturated in distilled water. (This should be prepared in small quantities, as it will only keep for a few days.)

No. 5. A solution of 100 grains bromide of potassium in eight or ten ounces of distilled water.

Having selected suitable paper, and cut it to the proper size, which should be at least an inch each way larger than the object to be represented, mark one of the corners with a pencil, so that the side on which the preparation is laid may be known, pin the paper by two of its corners to a board, and by means of a soft brush apply the preparation No. 1 carefully and smoothly to the surface of the paper, taking care to wash it thoroughly over without any mark of the brush, and that the solution is thoroughly absorbed. The paper may be suffered to dry by hanging from the board in the air, but without exposure to light.

When thoroughly dry it is ready for the next operation, which consists in pouring a portion of the second solution, just sufficient to cover the surface, into a shallow porcelain dish, which should be large enough to receive the paper. As only the prepared side of the paper should receive this solution, fold a narrow upright margin all round the paper, turning in the corners, holding it by two corners; let the side to which the previous solution has been applied, be drawn gently and smoothly over the surface of the solution, resting on it till it is thoroughly saturated. In this state it may remain for a few seconds, but not more than a minute, otherwise the nitrate solution may be decomposed by the iodine liquid.

The paper, now thoroughly saturated with the iodized liquid, is hung up in a proper place until about half dry. The paper is now thoroughly imbued with the preparation, and the nitrate of silver thoroughly decomposed; but it is now necessary to remove every trace of the salts with which the paper has been saturated. This Mr. Cundall accomplishes by floating the paper with its upturned margin on a basin of pure water for eight or ten minutes, drawing it occasionally gently along the surface to remove the soluble salts, which will separate from their own gravity; while the iodide of silver, being insoluble in water, remains upon the paper, presenting the surface required for a successful operation.

The paper should now be left to dry spontaneously, without being touched or the surface disturbed. When dry, it may be subjected to sufficient pressure to smooth it. In order to preserve its sensibility, it should be carefully secluded from the light, and placed in a portfolio. The paper thus prepared is called iodized paper ready for use.

For the third operation Mr. Talbot made use of the solutions 3 and 4 in the following manner :—Mix equal parts of the two solutions by means of the graduated drachm tube, but only in quantities required for immediate use, as it quickly loses its quality; Gallo-nitrate of silver is obtained by this means. With this mixture the iodized paper is washed over by means of another soft brush, using increased care in laying it on, so as to secure a smooth and even surface and equal distribution. Leave the solution to settle for eight or ten seconds, then dip the surface in pure water, still holding it by its upraised corners, and drawing the paper gently over the water several times; it is again drawn through a second course of fresh water two or three times. After being dried in the dark and at a distance from the fire, it is fit for use, and may be placed in the camera while the surface is dry, but still moist, or it may be placed in a portfolio with blotting-paper for future use. Mr. Cundall, and other recent operators, find it necessary to apply the gallo-nitrate as follows :—Pour out the solution upon a clean slab of glass, diffusing it over the surface to a size corresponding with that of the paper. Holding the paper by the narrow upturned margin, the sensitive side is applied to the liquid upon the slab, and brought in contact; so that by passing the fingers gently over the back of the paper, the surface is thoroughly wetted with the gallo-nitrate. Mr. Cundall further recommends, that in all cases when extreme sensitiveness is not required, the liquid should be diluted to one-half the strength indicated above, otherwise the paper is apt to be stained or embronzed, unless the manipulation be extremely well-managed. Rain, river, or spring water answers perfectly to *wash* the papers, distilled water being required for the silver solutions only.

These operations Mr. Talbot recommends should be performed with as little light as possible, and that should be candle light.

And now the paper is ready to place in the camera, where the operator is to use his own judgment in forming his pictures, and his experience in getting proper effect. According to the intensity of light and colour of the object, is the length of exposure, which may vary from five seconds to two minutes.

When the operation is terminated, it is necessary to develop the image by washing the surface over with a brush charged with the gallo-nitrate of silver, exposing it at the same time to a gentle heat from a hot iron or other similar body, held at the distance of an inch or two, the iron being held vertically, and the paper moved backwards and forwards so that it may all dry simultaneously. In the course of a few seconds the picture will become visible, usually of a fine blackish-brown colour.

When sufficiently developed, it is necessary to wash it immediately in pure water to remove the gallo-nitrate of silver. This last process of washing should be done before the paper has become quite dry, and, if necessary, the drying should be retarded by the application of hot vapour or a jet of steam. The final process is fixing the image.

This was accomplished by Mr. Talbot by dipping it first in water, and, after drying, washing it over with a solution of bromide of potassium. (Solution No. 5.) And, after a last washing in water, it is finally dried. A strong solution of common salt was substituted for the bromide of potassium, but was not so successful.

The present practice, as described by Mr. Cundall, is as follows:—In order to remove the sensitive matter from the picture, it is to be soaked, he says, "in warm water, but not warmer than may be borne by the finger. This water is to be changed twice, and the pictures are then to be well drained or dried in clean and dry blotting-paper, to prepare them to imbibe a solution of the hyposulphate of soda, which is prepared by dissolving an ounce of that salt in a quart (forty ounces) of water. Having poured a little of the solution into a flat dish, the picture is to be introduced into it; daylight will not now injure them. Let them soak for two or three minutes, or even longer, if they are strongly printed, turning them occasionally. The remaining unreduced salts of silver are thus thoroughly dissolved, and may now, with the hyposulphate, be entirely removed by soaking in water and pressing alternately in clean blotting-paper; but if time can be allowed, soaking in water alone will have the desired effect.

The impression now obtained is a negative, that is, the parts of the object which is white in nature are here represented black, and *vice versa*. From this impression, however, any number may be taken, having the lights and shadows as in nature. This is performed by placing upon the negative a piece of properly-prepared photographic paper, and in immediate contact with it, having previously rendered it as transparent as possible. By exposure to the light, the second impression is formed. The progress of the impression may be watched by raising one of the corners of the negative from time to time. The mode of rendering the negative transparent, as adopted by Mr. Fox Talbot, was as follows:—Grate some virgin wax on the back of the paper, and, having placed it between two pieces of white paper, draw a hot iron gently over it until the dissolved wax has throughly penetrated the paper of the negative, and rendered it somewhat transparent.

When many impressions are taken, the original loses a portion of its vigour, which may, however, be restored by dipping it again in the gallo-nitrate of silver, washing it in hot water, and fixing it as before directed. These impressions may be obtained by using calotype paper, but Mr. Talbot recommends photogenic paper prepared as follows:—

Having dissolved 25 grains of common salt in one ounce of distilled water, dip the paper selected and cut to a proper size in this liquid, leaf by leaf, leaving it there to soak for a short time, and place it between leaves of clean blotting-paper to dry; dissolve afterwards 90 grains of crystallized nitrate of silver in an ounce of distilled water, wash the paper on the seen silver side, with a soft pencil charged with this liquid, dry it a little, and pass another coating of the liquid over it, dry it thoroughly, suspending it for that purpose by one of the corners.

A more simple preparation of photographic paper is produced by dissolving 100 grains of bromide of potassium in an ounce of distilled water; dip the paper in this solution, place it as before between the leaves of blotting-paper, and when nearly dry wash the sensitive side with a solution of 100 grains nitrate of silver, dissolved in an ounce of distilled water; dry the paper in a darkened place, and, if required to be very sensitive, apply a second wash of the solution. This paper has presented the best results.

The impression obtained upon these papers in the manner described, form the calotype process. Their sensibility is such, that images of feathers, leaves, and other similar objects, are said to be obtained by the light of a jet of gas while still moist; holding the paper four or five inches from the flame, the impression will appear in three or four minutes.

The precautions to be taken during the preceding operations are as follow:—

1. It is necessary to have a clean brush for every solution, and to wash them carefully every time they are used. The brush used for the gallo-nitrate of silver is quickly destroyed.

2. The same blotting-paper should never be used but for the same solution, and it is better to have separate blotting-books prepared, with the names of the solution written on each.

3. The distilled and other waters should be changed with every operation.

4. Dr. Ryan observed that if the paper remained too long in the solution No. 2 (iodide of potassium), the iodide of silver was formed. He recommends, therefore, that the leaf should be dipped and removed promptly to prevent this formation.

5. Mr. Mitchell modifies the process in the following particulars:—He first applies the solution No. 2 (iodide of potassium), drys it; then the solution No. 1 (nitrate of silver), drys that also; and having dipped the paper for one moment in a solution of 125 grains of iodine, in an ounce of water, washes it in distilled water, and finally drys it. By this means Mr. Mitchell obtains a paper more sensitive, and, as is said, with the substances more equally distributed than by Mr. Talbot's process.

Improved Talbotype Process.—Many improvements have taken place in the Talbotype process. Mr. Talbot has himself introduced the following:—In order to get rid of the yellow tint in images taken on paper prepared with a solution of nitrate of silver, he proposes to plunge the paper after it is impressed into a hot bath, composed of hypo-sulphate of soda or other hypo-sulphate dissolved in ten times its weight of water, boiled to ebullition. The paper should remain about ten minutes in this bath, then be washed in cold water, and dried. By this means it is rendered both more permanent and more transparent; the lights are brought out better. The transparency of the paper can still be increased after this operation by the application of wax as already directed.

Another improvement consists in placing a hot iron plate behind the darkened frame, which covers the paper while it takes the image in the camera, thus communicating heat to the paper, and rendering it more sensitive.

I have been induced to give the formulæ of these different photographic authors, so that if the reader cannot arrive at a satisfactory result by one process, he may try another. And here I may as well remark, that the amateur should not be led too easily to try all the different processes he may hear or read of, for acquirement of a perfect knowledge of one of them is quite enough for a lifetime.

I am now about to introduce the reader to two photographers who have distinguished themselves by their successful practice in this process. I need scarcely say that the two-gentlemen I speak of are Sir William J. Newton, and J. D. Llewellyn, Esq.

Sir W. J. Newton's Process.—This gentleman has taken great interest in the art, and has materially contributed to its advancement by his own manipulation. I cannot, therefore, do better than give his formula in his own words, copied from the Journal of the London Photographic Society, to the writers of which I feel exceedingly indebted for much valuable information.

"*To Iodise the Paper.*—1st, Brush your paper over with muriate of barytes (half an ounce, dissolved in nearly a wine-bottle of distilled water); lay it flat to dry. 2nd, Dissolve sixty grains of nitrate of silver, in about an ounce of distilled water. Ditto sixty grains of iodide of potassium in another bottle with the like quantity of water. Mix them together and shake well; let it subside; pour off the water, and then add *hot* water; shake it well; let it subside; pour off the water again, and add three ounces of distilled water, and afterwards as much iodide of potassium as will redissolve the iodide of silver.

"Brush your previously-prepared paper well with this, and let dry; then place them in water, one by one, for about one hour and a-half or two hours, constantly agitating the water. As many as a dozen pieces may be put into the same water, one after the other, taking care that there are no air-bubbles; take them out, and pin to the edge of a board at one corner. When dry they will be ready for exciting for the camera by the following process:—

(These are supposed to be in six 1-ounce bottles with glass stoppers.)

1.	2.	3.
1 drachm of No. 4, 6 drachms of distilled water.	20 min. of No. 3, 6 drachms of distilled water.	A saturated solution of gallic acid.
4.	**5.**	**6.**
25 grains of nitrate of silver to half an ounce of water. Add 45 minims of glacial acetic acid.	2 drachms of No. 4, 6 drs. of water.	Equal parts of Nos. 1 and 2. N.B.—This must be mixed just before using, and the bottle cleaned afterwards.

"*To Excite for the Camera.*—Mix equal parts of Nos. 1 and 2, and with a glass rod excite the iodized paper and blot off; and it may be put in the slide at once, or the number you require may be excited, and put into a blotting-paper book, one between each leaf, and allowed to remain until required to be placed in the slide.

"*Time of Exposure.*—The time varies from three minutes to a quarter of an hour, according to the nature of the subject and the power of the sun; but five minutes is *generally* the proper time.

"*To Bring Out.*—Bring out with No. 3, and when the subject begins to appear, add No. 5; and when sufficiently developed, hold it up, and pour water upon it; then put it into hyposulphite of soda to fix it, for about an hour or more, and then into water; this is merely to fix it for the after process, at your leisure.

"*To Clean the Negative.*—Get a zinc tray about three or four inches deep, with another tray to fit in at the top, about one inch deep; fill the lower tray with boiling water, so that the upper tray may touch the water; put your solution of hyposulphite of soda, not strong, in the upper tray, and then your negatives one by one, watching them with care until the iodine is removed; then put them in hot water, containing a small piece of common soda (the size of a nutmeg to about two quarts of water), for about ten minutes; pour off the dirty water, and then add more hot water, shaking them gently for a short time; pour off the water again, and then add fresh hot water, and let it remain until it is cold, after which take them out carefully one by one, and put them in clean cold water for an hour or two; then take them all out together, and hold up to drain for a short time, and then put them between three or four thicknesses of linen, and press as much of the water out as you can; then carefully (for now all the size is removed) lay them out flat separately upon linen to dry.

"*Mode of Waxing the Negatives.*—Melt the pure white wax over a lamp of moderate heat, just merely to keep it in a liquid state; then fill the same deep tray as above described with boiling water, and with another similar to the upper one before described (which must be kept for this purpose only); put a clean piece of blotting-paper in this tray, and lay your negative face downwards, and with a soft flat hog's-hair brush, about an inch wide, dip it into the liquid wax, and brush the negative over, when it will be immediately transparent, and it can be done so that there is very little redundant wax; after which it may be put between two or three thicknesses of blotting-paper and ironed if necessary, which, however, should not be very hot, when it is ready to take positives from.

"*Positives on Negative Paper.*—Take one part of the iodide of silver before described, and add two parts of water; then add as much iodide of potassium as will redissolve it. Brush your paper with the foregoing, let dry, put into water, and proceed, in all respects, as above described for the negatives.

"*Excite for Positives.*—Excite with No. 1; blot off; lay it in your press, place the negative face downwards; expose to the light from ten seconds to half a minute, or more, according to the light (not in the sun), and bring out with No. 3; and when it is nearly developed add No. 1; then take it up and pour water upon it, and then place it in hyposulphite of soda (cold) until the iodine is removed; after which put it into alum water, about half a teaspoonful of powdered alum in two quarts of water; this will readily remove the hyposulphite, and also fix the positive more particularly; it will also take away any impurities which there may be in the paper; after which put it into clean cold water, and change two or three times.

"I have been thus particular in describing the process which I have adopted, more especially for beginners; and with great cleanliness and care in each process, and especially in keeping all the bottles with the chemicals free from dirt of every kind, the foregoing will lead to favourable results."

Mr. Llewellen's Process.—This gentleman, after stating that his method of manipulating is almost similar to Mr. Fox Talbot's process, says:—

"I have carefully followed the steps of its progress, and have, I believe, tried nearly all the modifications which have been at various times suggested, and it is remarkable that, in the long period which has now elapsed, no important improvements in paper photography should have been introduced.

"The paper which I use is manufactured by Turner, of Chafford Mills, and bears the water-mark of 'Turner's Patent Talbotype.' It is not free from faults; black specks, arising from brass and iron used in its manufacture, will often appear, but it is a firm compact texture, and makes good negatives, free from the woolliness which is fatal to other samples of paper which in other respects are superior.

"A sheet of this paper should be fastened with silver pins to a piece of flannel stretched over a board, and liberally brushed on one side with a solution of nitrate of silver, of the strength of thirty-three grains to the ounce of distilled water.

"In doing this, and in the subsequent manipulations, I use a brush formed of a flock of cotton wool, partly drawn through a glass tube, which thus makes a convenient handle; this arrangement was suggested by Mr. Buckle, and I believe, bears his name; it is known as a Buckle brush, and in my experience possesses advantages over a glass rod or triangle, or any of the other many contrivances which have been suggested, for the convenience of spreading solutions.

"As soon as the sheet of paper is partially, but before it is quite dry, say in about two minutes, it is to be immersed in a bath of iodide of potassium, of the strength of twenty grains to the ounce of water; all air-bubbles must be carefully got rid of; and the sheet will speedily assume a primrose-yellow colour, the back appearing nearly as bright as the face.

"It may now be shifted at once to a bath of water, which should be changed four or five times, and the paper allowed to soak in it for two or three hours, so as to insure the removal of all soluble salts, and leave a pure iodide of silver distributed throughout the substance of the paper.

"The whole of the process may be performed in full daylight.

"When thoroughly washed, each sheet is to be hung up separately, and when dry is improved by exposure for an hour or two to the full rays of the sun.

"It may then be subjected to strong pressure in a screw frame and kept for use; it will keep good for any length of time.

"To excite it for camera use, take three drops of aceto-nitrate of silver (*the aceto-nitrate consisting of fifty grains nitrate of silver with one ounce of water and one and a half drachm of acetic acid*), and three drops of a saturated solution of gallic acid; add these to one drachm of distilled water, which quantity will be about sufficient for a sheet of the ordinary size of 9 × 7 inches.

"In summer weather the above proportions are sufficient, but in winter, when the air is cold, four or five drops of aceto-nitrate, and four or five of gallic acid may be safely used to the drachm of water.

"This exciting solution should be liberally applied, in the same manner as that described for iodizing; the paper should be evenly and thoroughly wetted, and when well soaked, blotted off with a sheet of clean white blotting-paper. A round ruler rolled over it with a firm pressure, answers very well, and insures a uniform application.

"The paper is now ready for the camera, and should be screwed firmly into the holder, so as to exclude all air as much as possible. Under these circumstances it will keep damp for many hours, and may be depended upon to retain its whiteness, even in summer weather, for twelve hours.

"With a three-inch Ross lens, and a quarter-inch diaphragm, the time of exposure will vary from eight to fifteen minutes, according to the character of the light and the colour of the object to be copied. The exact time can only be taught by experience.

"In developing I make use of aceto-nitrate of silver, and solution of gallic acid in equal proportions, the same as directed for the exciting compound, but without the addition of any water. This must be mixed only immediately before it is wanted, as it decomposes with great rapidity; having prepared a sufficient quantity for a single sheet, say about one and a-half drachm, brush it over the excited side of the paper with a clean new brush.

"The picture ought now gradually and evenly to appear, beginning with the sky, and then faintly exhibiting traces of the darker parts and the shadows. At this point of the development I abandon the use of the compound mixture, and continue the action with the gallic acid alone. A Buckle brush (Fig. 63) is here of great service, as it enables the operator to add more of nitrate of silver, or more of gallic acid, as the case may require, to the different portions of the picture; and this is a very proper place to describe that article. A Buckle brush, then, is made as follows:—Procure a piece of glass tube, B, about half an inch in diameter and six inches long; have either a piece of silver wire, A, a little longer than the tube, and with a loop at one end, or a piece of silk thread, pass the wire or thread through the tube, and fasten to the end which comes through a tuft of clean cotton wool, C; by pulling the other end of the wire, it forms a very nice sort of brush for spreading solutions; the wool can be thrown away when dirty, and a fresh piece substituted; the loose end of the wire may be held in its place by bending it over the edge of the tube.

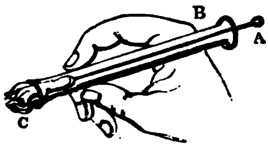


Fig. 63.

"In those parts where it develops too slowly, nitrate of silver may be chiefly used, while, on the other hand, the parts which are inclined to darken too quickly, may be brushed with the solution of gallic acid alone; and thus a more complete control over the development of the picture is obtained than can be effected by the use of the glass rod, or any other method that I am acquainted with.

"By this practice I have saved many pictures that must otherwise have been lost, and in many others again, have obtained a higher degree of excellence than would have been practicable under other treatment.

"In order to obtain a negative that will print well, it is better to carry the development further than may at first sight appear desirable, and it should be carefully examined by transmitted light before the operator is satisfied. When a full definition, even in the parts where the shadows of the landscape were the darkest, has been obtained, the photograph should, without delay, be well washed in cold water, and then immersed in a saturated solution of hyposulphite of soda, and left in this until all trace of the yellow iodide of silver has been removed.

"If this should prove tedious and difficult, as will sometimes be the case, it is well to pour away the solution into a stock bottle, and make a little fresh (*just enough* to cover *the sheet*), which will always, on application to the half-cleared picture, complete the removal of the yellow colour; and the new solution may be added to the stock bottle, and thus aid in keeping up its strength.

"The proof must now be thoroughly washed for an hour or more, in several waters, to get rid of all trace of hyposulphite of soda, which, if suffered to remain, would gradually destroy the picture.

"When thoroughly dried, it should be waxed, which may be done without risk, by laying the sheet between two pieces of blotting-paper saturated with ordinary white wax, and passing a moderately hot box-iron over the whole. A sufficient quantity of wax will be absorbed by the photographic negative, which will thus become transparent when viewed by transmitted light.

"It will print much quicker, and is less liable to injury from any chance contact with liquid, or from the humidity of the air, than if left unwaxed.

"The photograph is now finished.

"In the foregoing description I have descended into particulars which will, I fear, seem tediously minute, to those who are not aware how much, in photography, depends upon trifles. But I am convinced that the difference between the works of different operators mainly consists in the observance or the neglect of trifles seemingly altogether unimportant. Other formulæ besides those which I describe will, I well know, produce excellent results in the hands of skilful manipulators. I only speak of those methods which for some time past I have myself exclusively used, and by aid of which I have succeeded in making my best negatives.

"The practice is simple and certain, and I recommend it with confidence."

M. Le Gray's Process.—Among the many modifications of the calotype, we have that of M. Gustave Le Gray, who gives us the following directions:—

"*First Operation.*—Dissolve three hundred grains of isinglass in one pint and three quarters of distilled water (for this purpose use a water bath).

"Take one-half of this preparation while warm, and add to it as under:—

Iodide of Potassium	200 grains
Bromide of ditto	60 "
Chloride of Sodium	34 "

Let these salts be well dissolved, then filter the solution through a piece of linen, put it, still warm, in a large dish, and plunge in your paper completely, leaf by leaf, one on the other, taking care to prevent the air-bubbles from adhering to the paper.

"Put about twenty leaves at a time into the dish, then turn the whole, those at the top to the bottom, then take them out one by one, and hang them by one corner with a pin bent like the letter S, to dry spontaneously.

"When hung up, attach to the opposite corner a piece of bibulous paper, which will facilitate the drying.

"When the paper is dry cut it the size required, and preserve it in a folio for use; this paper may be made in the daytime, as it is not sensitive to light in this state.

"The bromide does not, in this case, act as an accelerator, as it does on the silver plates of the Daguerreotype, because, instead of quickening, it retards the operation a little; its action is to preserve from the gallic acid the white of the paper, which would blacken more rapidly if you employed the iodide of potassium alone.

"*Second Operation.*—Prepare, by the light of a taper, the following solution in a stoppered bottle—distilled water, six fluid ounces; crystallized nitrate of silver, 250 grains.

"When the nitrate is dissolved, add one ounce of crystallizable acetic acid; be careful to exclude this bottle from the light, by covering it with black paper. This solution will keep good until the whole is used.

"When you wish to operate, pour the solution upon a porcelain or glass slab, surrounded with a glass or paper border to keep the liquid from running off. I usually take the solution out of the bottle by means of a pipette, so as to prevent the distribution of any pellicle of dust or other impurity over the glass slab.

"Take a sheet of the iodized paper by two of the corners, holding them perpendicularly, and gently lower the middle of the paper upon the centre of the slab; gradually depress until the sheet is equally spread; repeat this operation several times until the air-bubbles disappear; take also the precaution to keep the upper side of the paper dry.

"In order to prevent the fingers from spotting the paper, pass a bone paper-knife under the corner of the sheet, to lift it from the slab between that and the thumb.

"Let the sheet remain upon the slab until the formation of the chloro-bromo-iodide of silver is perfect.

"This may be known by the disappearance of the violet colour which the back of the paper at first presented; it must not be left longer, otherwise it would lose its sensitiveness.

"The time required to effect this chemical change is from one to five minutes, depending upon the quality of the paper.

"Spread upon a glass, fitted to the frame of the camera, a piece of white paper well soaked in water; upon this place the prepared sheet, the sensitive side upwards.

"The paper which you place underneath must be free from spots of iron and other impurities.

"It is also necessary to mark the side of the glass which ought to be at the bottom of the camera, and to keep it always inclined in that direction when the papers are applied; if this precaution is neglected, the liquid collected at the bottom, in falling over the prepared paper, would not fail to produce spots. The paper thus applied to the glass will remain there for an hour without falling off, and can be placed within that time in the camera.

"When I am going to take a proof at a distance, I moisten the sheet of lining paper with a thick solution of gum arabic, and can thus preserve for a longer time its humidity and adhesion. I can also in this case make use of two glasses, between which the paper is placed, according to the direction of M. Blanquart Everard; but it is necessary to take great care that the plates of glass are perfectly clean, and to have them re-polished if scratched.

"I employ for this purpose, blotting-paper to clean them, as well as my plates; it is much superior to linen, and absorbs liquids and impurities that adhere to it. I never spare the blotting-paper, for I would rather use a leaf too much than be uncertain about the cleanness of my glass.

"When the sheet of lining paper adheres well to the glass, it should not be removed, but only moistened afresh with water, after which you may apply another sheet of the sensitive paper.

"In preparing several sheets of the sensitive paper at a time, it is not necessary to wash the slab for each sheet; you need only draw over it a piece of white paper to remove any dust or pellicle formed.

"When your operations are finished, you may pour back the aceto-nitrate of silver into a bottle, and reserve it for another time.

"The necessity of employing M. Gray's papers in a wet state is their most objectionable quality, but certainly the results obtained by strict attention to his directions are often exceedingly beautiful. For developing the image the following is recommended, which does not, however, differ essentially from the developing processes already described:—

"Make about a pint bottle of saturated solution of gallic acid, having acid in excess, and using distilled water; decant a portion into a smaller bottle for general use, and fill up the other bottle; you will thus always have a clear saturated solution.

"Pour upon a slab of glass, kept horizontal, a little of this liquid, spreading it equally with a slip of paper, then apply the paper which has been exposed in the same manner as described for the negative paper, being careful to keep the back dry. Watch its development, which is easily observed through the back of the paper; you may leave it thus as long as the back of the image does not begin to spot.

"When it is rendered very vigorous, remove it quickly to another clean slab, and well wash it in several waters, occasionally turning it, and gently passing the finger over the back; by this means you remove any crystals of gallic acid which might spot the picture.

"The appearance of thei mage at the end of this process will enable you to judge if it was exposed in the camera the proper time.

"If it becomes a bluish grey all over, the paper has been exposed to long; if the strongest lights in the object, which should be very black in the negative, are not deeper than the half tints, it has still been too long exposed; if, on the contrary, it has been exposed too short a time, the lights are but slightly marked in black.

"If the time has been just right, you will obtain a proof which will exhibit well-defined contrasts of black and white, and the light parts very transparent. The operation is sometimes accelerated by heating the gallic acid, and by this process the dark parts of the picture are rendered very black.

"To fix these negative proofs, a very strong solution of hyposulphite of soda, about one ounce of the hyposulphite of soda to four fluid ounces of water, is employed, and the picture is allowed to remain in it until every trace of yellowness is removed from the paper."

Dr. Diamond's Process.—There is one more formula which deserves notice—I mean that of Dr. Diamond, who has been a very successful follower of this process; and I think the reader will be much benefited by a careful perusal of his remarks in his own words:—

"More failures," he says, "than any others depend upon not having good iodized paper, which may result—

"1. From the quality of the paper;

"2. The mode of preparing it;

"3. The want of proper *definite* proportions for a particular make of paper; because I find very different results ensue unless these things are relatively considered. I have not met with satisfactory results in iodizing the French and German papers, and the thick papers of some of our English makers are quite useless.

"Turner's paper of the 'Chafford Mills' make is greatly to be preferred, and therefore I will presume that to be used, and of a medium thickness. The great fault of Turner's papers consists in the frequent occurrence of spots, depending upon minute portions of brass coming from the machinery, or from the rims of buttons left in the rags when being reduced to pulp; and thus a single button chopped up will contaminate a large portion of paper. Occasionally these particles are so large that they reduce the silver solutions to the metallic state, which is formed on the paper; at other times they are so minute as to simply decompose the solution, and white spo are left, much injuring the effect of the picture.

"Whatman's paper is much more free from blemishes, but it is not so fine a compact in its texture, the skies in particular exhibiting a minutely-speckled appe ance, and the whole picture admitting of much less definition.

"It may not be inappropriate to mention here, in reference to the minutene attainable by paper negatives, that a railway notice of six lines is perfectly legible, a even the erasure for a new secretary's name is discernible in a specimen, which w obtained with one of Ross's landscape lenses, without any stop whatever being use and after an exposure of five minutes *during a heavy rain*. The sky was scarcely dense as could be desired, which will be accounted for by the dull state of the atmo phere during the exposure in the camera.

"Having selected your paper as free from blemishes as possible, which is mo readily ascertained by holding it up to the light (the rejected sheets doing perfectly well for positives, it is well to reject *all* those upon which *any* doubt exists), mark the smoothest surface; the touch will always indicate this, but it is well at all times not to handle the surfaces of papers more than can be avoided. There is much difference in this respect; some individuals will leave a mark upon the slightest touch, whereas others may rub the paper about with perfect impunity.

"I prefer the paper to be iodized by the single process, because, independently of the ease and economy of time, I think more rapidity of action is attained by paper so treated, as well as a greater intensity of the blacks, so requisite for producing a clear picture in after-printing.

"Take sixty grains of nitrate of silver and sixty grains of iodide of potassium, dissolve each separately in an ounce of distilled water, mix and stir briskly with a glass rod so as to insure their *perfect* mixture; the precipitated iodide of silver will fall to the bottom of the vessel; pour off the fluid, wash once with a little distilled water, then pour upon it four ounces of distilled water, and add 650 grains of iodide of potassium, which *should* perfectly re-dissolve the silver and form a clear fluid; should it not (for chemicals differ occasionally in their purity), then a little more should be very cautiously added until the effect is produced.

"The marked side of the paper being laid upon the surface of this fluid in a proper porcelain or glass dish, immediately remove it, lay it upon its dry side upon a piece of blotting-paper, and stroke it over once or twice with a glass rod; this as effectually expels all the particles of air as complete immersion, it is also more economical, and has the advantage of requiring much less time in the after-immersion in the 'hypo' when it is required to remove the iodide. Either pin the paper up, or lay it down upon its dry side, and when it becomes tolerably dry (perfect dryness is not requisite) immerse it in common cold water for the space of four hours, changing the water during that time three or four times, so that all the soluble salts may be removed; often move the papers, so that when several sheets are together, the surface of each may be equally subjected to the water.

"If this paper is well made it is of a pale straw colour, or rather primrose, and perfectly free from unevenness of tint. It will keep good for several years; if, however, the soluble salts have not been *entirely* removed, it attracts damp, and becomes brown and uncertain in its application.

"Upon the goodness of your iodized paper, of course, depend the future results. Although it is not requisite to prepare it by candle-light, which in fact is objectionable om your inability to see if the yellow tint is equally produced, I think it should not exposed to too strong a light; and as the fly-fisher in the dull winter months pre-res his flies ready for the approaching spring, so may the photographer, in the dull eather which now prevails, with much advantage prepare his stock of iodized paper ady for the approach of fine weather. Many other ways have been recommended hich have proved successful in different hands. Dr. Mansell, of Guernsey, pours the dide solution upon his paper, which previously has had all its edges turned up so as resemble a dish; he rapidly pours it off again after it has completely covered the per, and then washes it in three waters for only ten minutes in all; he considers at thereby none of the size of the paper is removed and a more favourable action is tained. In the experiments I have tried with the air-pump, as recommended by r. Stewart, I have met with much trouble and little success; and I am inclined to tribute the very beautiful specimens which he has produced to his own good manipu-tion, under favourable circumstances.

"To excite the paper take 10 drops (minims) of solution of aceto-nitrate of silver, d 10 drops of saturated solution of gallic acid, mixed with 3 drachms of distilled ater.

"The aceto-nitrate solution consists of—

Nitrate of silver	30 grains.
Glacial acetic acid	1 drachm.
Distilled water	1 ounce.

"If the weather is warm, 6 drops of gallic acid will suffice; and the excited paper hus prepared may be kept longer.

"This may be applied either directly by means of the glass rod, or by floating, as before, and then with the glass rod. If floating is resorted to, then a larger quantity must be prepared. The paper should be blotted off by means of blotting-paper (which should never be used more than once, although preserved for other purposes), and put into the dark frames for use. It is not requisite that the paper should be perfectly ry. This exciting should be conducted by a very feeble light; the paper is much more sensitive than is generally supposed; in fact, it is then in a state to print from, by the aid of gas or the light of a common lamp, and very agreeable positives are so produced by this negative mode of printing.

"I would advise the aceto-nitrate of silver and the solution of gallic acid to be kept in two bottles with wooden cases differing in their shape, so as not to mistake when operating in comparative darkness. A quarter of an ounce of gallic acid put into a three-ounce bottle, and *quite* filled up with distilled water as often as any is used, will serve a very long time.

"I would advise that the paper should be excited upon the morning of the day when it is intended to be used; for there is no doubt the longer it is kept, the less active and certain it becomes. I have, however, used it successfully eight days after excitement, and have a good negative produced at that length of time. The general medium time of exposure required is five minutes. In the negatives exhibited, the time has varied from three minutes to eight, the longer time being when the day was very dull.

"The pictures should be developed by equal quantities of the aceto-nitrate of silver and the saturated solution of gallic acid, which are mixed and immediately applied to the exposed surface. This may be done several hours after the pictures have been removed from the camera. Care should be taken that the back of the picture does not become wetted, as this is apt to produce a stain which will print off upon the positive.

"If, upon the removal of the paper from the slide, the picture is very apparent, by first applying a little gallic acid and immediately afterwards the *mixed* solutions, less likelihood is incurred of staining the negative, from its being more evenly and intensely developed.

"If browning takes place, a few drops of strong acetic acid will generally check it. Should the picture be very tardy, either from an insufficient exposure, want of light, or other cause, a few drops of a solution of pyrogallic acid, of three grains to the ounce of water, and a drachm of acetic acid, will act very beneficially. It sometimes gives an unpleasant redness upon the surface, but produces great intensity upon looking through it. Until the pyrogallic solution was added, there was scarcely anything visible upon this paper, the failure having in the *first* instance happened from the badness of the iodized paper.

"As soon as the picture is sufficiently developed it should be placed in water, which should be changed once or twice; after soaking for a short time, say half an hour, it may be pinned up and dried, or it may at once be placed in a solution almost saturated, or quite so, of hypo-sulphite of soda, remaining there no longer than is needful for the entire removal of the iodide, known by the disappearance of the yellow colour.

"When travelling, it is often desirable to avoid using the hyposulphite, for many reasons—among others, getting rid of extra chemicals; and it may be relied on that negatives will keep even under exposure to light for a very long time. I have kept some myself for several weeks.

"The hyposulphite, lastly, should be effectually removed from the negative by soaking in changed waters.

"Some prefer to use the 'hypo' quite hot, or even boiling, as thereby the size of the paper is removed, allowing of its being readily afterwards waxed. I have always found that pouring a little boiling water upon the paper effectually accomplishes the object; some negatives will readily wax even when the size is not removed. A very hot box-iron is best for the purpose; but the most important thing to attend to is, that the paper should be perfectly dry; and it should therefore be passed between blotting-paper and well ironed before the wax is applied. Negatives will attract moisture from the atmosphere, and therefore the ironing should be resorted to immediately before the application of the wax.

"Before concluding these remarks, I would draw the attention of the reader to the great convenience afforded by a yellow bag, made so large as to cover entirely the head and shoulders, and confined round the waist by means of a stout elastic band. In a recent excursion, I have with the greatest ease been enabled to change all my papers without any detriment whatever, and thereby dispensed with the weight of more than a single paper-holder. The bag is no inconvenience, and answers perfectly well, at any residence you may chance upon, to obstruct the light of the window, if not protected with shutters.

"I would also beg to mention that a certain portion of the bromide of silver introduced into the iodized paper seems much to accelerate its power of receiving the green colour, as it undoubtedly does in the collodion. Although it does not accelerate its *general* action, it is decidedly a great advantage for foliage. Its best proportions I have not yet been able to determine.

"I would also offer a caution upon too great reliance being placed upon the use of gutta-percha vessels when travelling, as during the past summer I had a bottle containing distilled water which came into pieces, and I have now a new gutta-percha tray which has separated from its sides. This may appear trivial, but when away from home the greatest inconvenience results from such accidents, which may be easily avoided."

Mr. Stewart's Process has been alluded to by Dr. Diamond, and having some claim to the merit of originality, I shall introduce it here, as it may prove useful to some of our amateur photographers, premising that the use of the air-pump, as directed by Mr. Stewart, is highly useful in iodizing the paper in the wax paper process. In the description of his process, Mr. Stewart says:—

"I shall confine myself, for the sake of brevity, to the manipulatory details necessary for the production of negatives.

"*Paper.*—I prefer to all others Whatman's make, as supplied to me by Mr. Sandford; it is rather thick, and does not readily absorb the wax necessary to render it sufficiently transparent; but these objections can be overcome, as will be hereafter explained, while it gives a minuteness as well as mellowness of detail which I have not found in any other. Canson's French paper, and the paper known as 'Papier Saxe,' are good papers, and the most easily handled, being strong and tenacious in their texture. Both stand the action of the air-pump perfectly; the former requires to be carefully selected, it is so irregular and full of defects, but gives very intense blacks; the latter is regular and good, as far as my experience of it goes; it requires longer exposure than the others, being less sensitive when prepared.

"*To Iodize the Paper*, prepare a solution in the following proportions:—Dissolve one ounce (480 grains) of iodide of potassium, and 30 grains of bromide of potassium (I often omit the bromide) in twenty ounces of distilled water, and filter.

"For Whatman's paper it is advisable to reduce the iodide of potassium one-fifth —to about 380 or 400 grains. Pour this solution into a tray, and having cut sheets of paper a little larger than the size finally required for the camera (this is desirable, as the borders are always more or less defective in iodizing, and the paper may, after that operation, be cut to the exact size required), place one sheet floating on the solution, then slip the next sheet edgeways underneath the first, as it floats—doing this smartly, so that the sheet may not lose its rigidity before it has been slid fairly under the first sheet; repeat this with every successive sheet—as many, if necessary, as the depth of the solution in the tray will permit. Any other mode of placing the sheets in the tray will answer, but the above is a rapid, simple, and effectual way of immersing the sheets in the bath, so as to avoid the presence of air-bubbles, and may be employed on all similar occasions. When all the sheets are immersed, cover the upper one with the liquid by raising the whole bundle of the sheets together, and reversing them in the bath, the upper sheet being thus undermost. In four or five minutes, while still in the bath, roll this bundle of sheets up loosely, small enough to be dropped into the glass cylinder, in connection with an air-pump.

"The pump I use is a simple direct-action one; the flexible tube attached to it, and through which the air is exhausted, finishes in a flat lid lined with Indian-rubber (having a valve in the middle), which is placed on the top of, and hermetically closes, an upright glass cylindrical vessel. When the roll of paper is dropped into the glass cylinder, pour over it the solution in the tray in sufficient quantity to cover the paper, and force a piece of gutta-percha or glass down to the top of the roll, in order to prevent its rising in the cylinder, while the air is being exhausted. Then placing the lid on the ground top of the cylinder, a few strokes of the pump suffice to exhaust the air, and the action may be continued as long as the air-bubbles are observed to escape from the paper to the surface. Generally speaking, four or five minutes suffice for this operation, and the paper may be left a few minutes more *in vacuo* before being removed from the pump. The roll is then picked out, or upset into the tray, and the liquid again poured over it, so that the floating sheets may be easily separated as they are taken out and hung up one by one on an extended cord to dry without previous washing in water. They are now ready for use as required. The operation may be conducted in ordinary daylight.

"With Canson's paper and the 'Papier Saxe,' their sizing is so tenacious there is no fear of continuing the action of the pump too long; but care must be taken with Whatman's paper in submitting it to the action of the pump, as it loses its sizing with great facility. I believe this has been obviated in the more recent manufacture, but it has been an obstacle to the use of that paper. The unsizing is indicated while under the pump, by the presence of a glutinous froth on the surface of the liquid, which does not disappear as bubbles do in water. When the quantity of size set free is very small, the paper may still be used with safety; but the defect is generally discovered in the first sheet used, while developing in the bath of gallic acid. The destruction of the body of the paper, hitherto imperceptible, is now seen, if it exist, while examining the sheet by transparence; and in that case the whole batch iodized had better be set aside, as it is probable most of the sheets are injured. This paper, when perfect, will keep many months, or a year; and as paper thus prepared is employed in all the following processes, a quantity sufficient for a month's consumption can be iodized at once, and put to the necessary test. Should Whatman's paper be now manufactured of sufficient tenacity to resist the action of the pump, there will remain no uncertainty as to its being perfectly iodized and uninjured, and the only cause of failure with that paper removed.

"The solution of iodide of potassium can be preserved indefinitely (replenished only with fresh to replace the quantity absorbed), if it is regularly filtered after use. Should it become very yellow, putting into the bottle a small quantity of starch, and allowing it to digest for some hours, then filtering it, will restore to it its primitive purity.

"*To Render the Paper Sensitive.*—This operation must be performed by the light of a candle or a yellow curtain. In five ounces of distilled water dissolve half an ounce (or 240 grains) of nitrate of silver, and thereto add five drachms of glacial acetic acid, and filter the solution.

"*1st Method.*—Pour the above solution into a perfectly clean tray (which should never be employed for any but silver solutions), and float a sheet of iodized paper on its surface, extending the sheet rapidly, beginning at one end, and lifting it once or twice by the corners, to see that there are no air-bubbles; then cover it up, and leave it thus floating on the silver solution for ten to twelve minutes, or even a quarter of an hour, as it is essential that the solution should thoroughly penetrate the thickness of the paper.

"Should the quantity of the silver bath at hand be small, in lieu of pouring it into a tray (which is rarely quite flat), sufficient may be poured on a plate of glass (the glass, if need be, of a slider), levelled so that none should flow over the sides, and the sheet of paper floated thereon for the same length of time. During this interval, prepare the glass or slate of the camera slides by placing it beside you carefully levelled. If a glass, it had better be finally cleaned with a few drops of acetic acid, to remove any grease, so that water may flow readily over it. Upon this glass or slate pour a layer of rain or distilled water, just sufficient to cover it. Then taking a sheet of thick bibulous paper (printing) cut to the size of the glass, lay it thereon, so that it at once imbibes the water on the glass, to which it adheres without air-bubbles, and becomes a wet lining to receive presently the sensitive sheet of paper; the excess of water must be removed by lifting up the glass by the corner. Pour over this lining another layer of pure water, and then, on the expiration of the ten or twelve minutes, lift the sheet of sensitive paper carefully up from its bath by the corners, allowing it to drain for a moment; deposit it, floating on the paper lining, the sensitive side (that which was in contact with the silver bath) uppermost towards the operator. The intervening layer of water permits of the sheet being easily adjusted in its proper position; then seizing the glass, and corners of the sheets to prevent them slipping between the fingers and thumb, tilt up the glass slowly and gently so as to allow the intervening water to escape by one corner, when the two sheets will adhere firmly to each other and to the glass, without the presence of air-bubbles. Leaving the glass for a minute or two upright, with the same corner downwards, to allow all the excess of moisture to disappear, it may now be placed in the slider, ready for exposure, taking care not to reverse its position for some few minutes more, lest any drop should re-traverse the sheet and leave a stain. The chief use of the layer of water in this operation, is to prevent the presence of air-bubbles; it also secures the proper position of the sheet without handling it, which, with Whatman's paper, as at present made, is to be avoided as much as possible, it tears so easily. An experienced manipulator can, however, dispense altogether with the layer of water.

"The paper thus prepared for exposure preserves its extreme sensitiveness with its moisture, which, according to weather and climate, may endure an hour or two, within which limit, therefore, the sheet ought both to be exposed and developed. In winter, and cold damp weather; it may remain moist eight or ten hours. When the view to be taken can be reached within that interval of time, this mode of preparing the paper, on which the image is intended to fall directly on the sheet of paper without intervention, the most rich and delicately beautiful results are obtained.

"The time of exposure depends as usual upon the intensity of the light, and upon the nature of the view, whether abounding or not in deep shadows, and also upon the length of the focus and diameter of the diaphragm. With a 3-inch lens, focus of 14 to 15 inches, and diaphragm of 6-10ths of an inch diameter, the exposure for ordinary landscape may vary from a quarter of an hour to half an hour. Paper thus prepared bears very prolonged exposure without injury; I am therefore guided in my operations by the nature and composition of the view; by its darker portions, without much reference to the brighter lights. I also find it safer to expose it a few minutes longer than may be sufficient, no injury resulting from so doing.

"*2nd Method.*—In order to preserve the paper moist in all weathers for one or two days, so as to permit of distant excursions, the following modification of the preceding plan should be adopted. In this operation it is necessary to employ double glasses to the sliders, the paper being placed between the glasses:—

"Plunging the iodized sheet into the silver bath, instead of merely floating it on the surface, cover it entirely with the liquid, avoiding air-bubbles. After remaining 10 minutes in the bath, lift up the sheet, allowing it to drain for a moment, and convey it into another bath of distilled or clean rain-water, to wash off some of the excess of the nitrate of silver. If the paper is to be used within ten or twelve hours, five minutes' washing will quite suffice; if not till the next day, the washing should be prolonged to ten or fifteen minutes. Should the distilled water, after washing several sheets, become milky, it had better be renewed.

Placing the smaller glass (that which is nearest the lens during the exposure), carefully cleaned with a few drops of acetic acid, on a level,* pour on it a layer of distilled or rain-water. Upon this, float as before the sheet of sensitive paper removed from its water-bath. In this instance it is of no consequence which side of the sheet is downwards, as it is sensitive throughout and on both sides. Inclining the glass, the paper will adhere to it by the escape of the water. Then replacing the glass, with its adhering sheet, on the level, let it be immediately covered with a sheet of wet bibulous paper (or a layer of water can first be extended, and the lining sheet be at once soaked by being floated thereon and adjusted to cover the sensitive sheet, and the intervening water drained off as before), and retaining the glass in the left hand, with the edge of the second glass of the slider grasped in the right hand, inclined at an angle of forty-five degrees, rub twice down the surface of the bibulous paper from one end of the glass to the other, sufficiently hard to force out all the moisture possible, without tearing the paper itself. The second glass is then immediately applied to the paper, to which it clings firmly, is evenly adjusted to the other, and wiped dry; the two adhering glasses, with their imprisoned sheets, are then placed in the slider ready for exposure. Sheets thus prepared remain moist a day or two, and are but little less sensitive than those prepared as first described.

"A *Third Method*, which in certain circumstances may be convenient, is to prepare an iodized sheet, by leaving it immersed as above in the silver bath for ten or twelve minutes, washing it in distilled or rain-water for twenty minutes thereafter, and again in a second bath of distilled water, if desired to remain sensitive for more than one or two days. On removal from the water, hang it up to dry, or, if hurried, dry it between several successive sheets of clean and new blotting-paper.

"To those in the habit of using Mr. Le Gray's waxed-paper process, or any of its modifications, I would recommend, in preference to this last method, to iodize their wax-paper with the air-pump, and use a silver solution of the strength here noted. I have found a decided superiority in the waxed-paper prepared *in vacuo;* it possesses greater vigour, and is capable of much longer exposure without injury.

"In all these processes, the iodide of silver not being confined to the surface of the paper, as in other paper processes, but penetrating the body of the paper, a somewhat greater quantity of silver is expended; and I would recommend all beginners, until they have had some experience, to use in every instance fresh solutions if possible.

"The aceto-nitrate of silver solution should always be colourless; it does not, however, long remain so—discolouring in a day or two. The most effectual way of purifying it, preferable to the use of charcoal *à noir animal*, is, I find, to treat it as follows:—Put a small quantity—say a teaspoonful or less—of kaolin (decomposed felspar employed by the porcelain manufacturers) into about eight or ten ounces of the solution, in a transparent bottle, where it acts as a filter; shake up the solution and expose it to the ordinary daylight for a few minutes, in order to complete the decomposition already commenced, by which time the felspar has subsided, and then the liquid filtered will pass clear; a few crystals of the nitrate of silver can be added, to restore the strength of the solution.

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* I employ, as a very light portable level, a triangle of brass, formed of three pieces, attached together at the corners by screws, which at the same time can be raised or depressed to produce a level. The withdrawal of one of the screws permits of the pieces being shut up into the size of a small ruler.

"*To Develop the Picture.*—An operation also to be conducted by yellow light. The sheet, picked off the slate or removed from between the glasses, is extended as rapidly and uniformly as possible on the surface of, and then immediately covered with, a saturated solution of gallic acid; say a drachm of gallic acid dissolved in a pint and a half of water. This solution should only be prepared when required, and heated a little to hasten its dissolution if necessary.

"A sheet prepared by the first method should be placed in the gallic acid for development, before it has become quite dry, lest it should detach itself from the slate and become stained by touching the slider. For the sheets between glasses, several hours may intervene between the exposure and development.

"If the paper has been sufficiently acted upon by the light, as is almost invariably the case, the development will take place effectually in the simple gallic acid bath. The length of time required varies with the circumstances and the paper employed. Canson's paper develops rapidly, in one or two hours on the average. The paper Saxe is longer in beginning to appear, and then proceeds rapidly. Whatman's paper, though the most sensitive, is the slowest to develop, but supports best the action of the gallic acid. Sometimes two or three hours will suffice for it, but very often ten or twelve hours are not too much, and, if convenient, by removal into a fresh bath of gallic acid, after the first has become dissolved and turbid, it may be left with safety, and often with advantage, double that time in the gallic acid bath. The completion of the development is best ascertained by examining the sheet by transparence. When the whites begin to lose their brilliancy, when the blacks become opaque and well penetrated, it should then be transferred to a tray of clean water. A little experience will serve to indicate when the development is complete, without the necessity of lifting or handling the sheet frequently; the view then appears to be almost lost under a misty veil. The development should even be pushed beyond this point, as the details in the whites (which represent the shadows of the picture) only appear at the very last.

"The stains similar to marbling that are complained of as frequently occurring at this stage of the operations, proceed sometimes from insufficient saturation in the silver bath, but often also from want of cleanliness. To assist in guarding against this last cause, it is well to adopt the practice of never separating the sensitized sheet from its paper lining; but removing the two sheets together from the slider, immerse them so in the gallic acid bath, and leave them thus, the lining undermost, until the development is complete. The sheet is thus preserved by the bibulous paper from the stains occasioned by the deposit on the bottom of the tray. This practice has farther the advantage of enabling the manipulator to handle a large sheet of paper without fear of its tearing, as it otherwise so frequently does by its own weight when lifted.

"In the case of papers sensitized by the second or third methods described above, some eight or ten drops of the silver solution may be added to the gallic acid bath, after the sheet has lain in the bath some ten or fifteen minutes; but this is not always necessary.

"After an hour's immersion in the gallic acid bath, should any of these sheets, when examined by transparence, show blacks still very feeble, owing to insufficient exposure, they can be placed in a fresh gallic acid bath to which ten or twenty drops of the silver solution have been previously added; the opacity of the black is thus considerably increased by the deposit of silver on them which is thus determined. But this resource should be employed with much circumspection, because it tends to diminish the harmony of the view, by rendering the contrast between the lights and the shadows harsher than they are in nature, depriving the shadows of their due transparency, and producing the unnatural effects seen in some photographic landscapes. The various accelerating processes so frequently recommended, appear to be but this: the exposure in the camera being too rapid to permit of the image appearing under the influence of feeble re-agents, recourse is had to those more powerful, which will always produce an image, provided the paper itself can, without staining, support their action. Hence these processes only succeed well on glass, which can resist their action uninjured. But those chemical re-agents destroy the natural harmony of the image, substituting an artificial effect; because their action, bearing in preference on the blacks, proceeds faster than in the proportion of the action of the light upon each point in the camera. Thus very rapid, but less perfect, proofs are obtained.

" *To Fix the Negative.*—On the removal from the gallic acid bath, the sheets (still by candle-light) should be washed in two or three waters for a quarter of an hour, or they may be left in the water indefinitely till it is convenient to proceed with them; then plunged in a bath of either hyposulphite of soda, or bromide of potassium of the strength of one ounce of either to six or eight ounces of water, or stronger. This process is preferable when abroad, as it does not expose the operator to the risk of staining his work, which the former is so apt to do. When the negative has lain in the hyposulphite bath for about fifteen minutes, it may be examined by daylight to see whether the yellow colour, visible on the back of the negative, or more easily by transparence, has disappeared. If so, the dissolution of the yellow iodide of silver is effected and the operation is terminated. The sheet is then thoroughly washed in water, frequently changed, for several hours. A quarter of an hour or half an hour in the bromide bath suffices to fix the negative temporarily; but it must be fixed as above by hyposulphite of soda on return home.

" The final process, which is generally necessary (though with some of these papers it may be dispensed with), is to wax the negative, when perfectly dry, in order to render it more transparent when required for printing. The most simple mode of accomplishing this is to place the negative face downwards on a sheet of clean paper, rubbing a piece of white wax on a clean heated German iron till the wax melts; spread it all over the proof, as much as it will imbibe. When the sheet is saturated, place it successively on two or three sheets of thick blotting-paper, ironing it all the time till it has parted with its excess of wax. Care must be taken that the iron employed is not too hot; the wax should melt freely when it touches, but without ebullition.

" Whatman's make of paper is sometimes inconveniently thick for printing from, and also receives the wax with difficulty. In that case, after fixing, but before waxing, the negative should be submitted for about half an hour to a bath of concentrated sulphuric acid in the proportion of one ounce to six ounces of water, and then thoroughly washed in several waters. This destroys the sizing, and renders the negative very transparent without injury.

" These directions appear much more tedious in description than they will be found in practice; by following them, paying special attention to cleanliness, the results are so regular and constant, accompanied with so little variation in their repetition under any circumstances, that I think very little experience will suffice to render any beginner expert and certain in his operations. Unless some accident, independent of the process, intervenes, it rarely indeed happens that on going out for the day with three or four sheets, I do not return with as many different and passable views, no matter almost what the weather may be.

"The second of the preceding methods I find the most convenient for use when absent from home; and where one can carry a small hood, or any means of changing the papers in the sliders protected from daylight, it is necessary to have but one slider, as a thin box will carry six, eight, or ten double glasses with their prepared sheets, to be successively exposed in the same slider as required. I have little doubt, with the aid of the nitrate of zinc, these may, without any material diminution of sensibility, be preserved moist for many days, since at present, with a little precaution they retain their moisture two or three days, particularly if thick English paper has been used."

New Processes.—Many new applications of the calotype processes have been proposed and practised with some success, showing how universal the principle involved prevails in nature. A brief summary of some of these may not be uninteresting to the reader:—

Cyanotype was so called by Sir John Herschel, cyanogen in combination with iron forming a leading part in the process. A piece of paper is washed over with a solution of ammonio-citrate of iron, sufficiently strong to be of a sherry colour. Expose the paper in the camera, and develop the picture by washing it sparingly with common yellow ferro-cyanate of potass, when the negative disappears, and is replaced by a positive of a violet colour, on a greenish-yellow ground.

The *Energetype* consists in the application of a solution of succinic acid two drachms, common salt five grains, mucilage gum arabic half a fluid drachm, distilled water one fluid drachm and a-half, to paper which is afterwards, when nearly dry, washed with solution nitrate of silver, containing one drachm of the salt, to an ounce of distilled water; the paper is exposed in the camera. The image is brought out by the application of a solution containing a drachm of concentrated solution of green sulphate of iron, in two drachms and a-half of mucilage gum arabic.

Amphytype is also a discovery of Sir John Herschel, and receives its name from the fact, that negative and positive pictures can be produced by one process. Paper may be prepared either with the ferro-tartrate or the ferro-citrate of the protoxide of mercury or of lead, by using the cream of the salts, or by successive applications of the nitrates of their oxides, alternating with solutions of the ammonia-tartrate of iron. The proportions of the process are not yet fixed.

THE WAX PAPER PROCESS.

Dr. Percy's Process.—We shall now consider a twin branch of the art. I allude to the wax paper process, first practised by M. Le Gray, and since very successfully by several eminent photographers, amongst the most successful of whom stands Mr. Fenton, whose beautiful views of several cities and places in Russia were all taken by this process; in fact, it is the most useful of any to the traveller who does not wish to be troubled with the incumbrances necessary to the successful practice of collodion; and the remarks of Dr. Percy, which I subjoin, bear me out in this assertion.

Dr. Percy, after remarking that "there is no field in science which promises, at the present time, a richer harvest to those who possess the scientific acquirements which qualify them for its cultivation than photography," continues:—

"Last summer, 1852, it will be remembered, the temperature was unusually high, particularly in the early part of July, the thermometer frequently indicating 90° Fah. in the shade. We shall all long remember the tropical character of that sultry season, —the sun shining without a cloud for days in succession. I heard numerous complaints from photographers, to the effect that they had great difficulty in obtaining pictures, whether on collodionized plates, or on paper; and I met with numerous failures myself with the paper process. There can be no doubt, I think, that these failures were entirely occasioned by the high temperature of the season. I had, before, been constantly accustomed to work successfully with the ordinary paper process in taking landscape views; the iodised paper being excited on the morning of a calotype-excursion, and the image developed in the evening on returning home, after wandering over hill and dale many a mile.

"In cold weather, I have taken tolerably good pictures some days after the excitement of the paper; but, in the season mentioned, I was unable to produce pictures at all satisfactory, unless the process of development took place immediately, or very shortly, after the slide was withdrawn from the camera. The image, if developed at a later period, was most unsatisfactory—the defect being especially conspicuous on viewing the negative by transmitted light. It was porous, and particularly so on the darker parts. The process which I employ is as follows:—

"1. *Solution for the Single Wash.*—To 100 grains of nitrate of silver, dissolved in five fluid ounces of water, add 980 grains of iodide of potassium, which is rather more than sufficient to form a clear solution with that quantity of nitrate.

"2. *Exciting Liquid.*—Seventy-five grains of nitrate of silver, dissolved in one and a-half fluid ounce of water, to which are added two drachms of glacial acetic acid. One or two drops of this solution (known as aceto-nitrate of silver) to one drachm of distilled water, to which are added one or two drops of aqueous solution of gallic acid.

"3. *Developed* by aceto-nitrate and gallic acid diluted with once or twice the volume of water.

"With the waxed paper, on the contrary, I met with excellent results during the hottest part of that sultry season, having obtained a good picture after subjecting it to the following severe test:—I excited the paper in the morning about ten o'clock, and immediately afterwards exposed it in the camera. I withdrew the slide containing the paper, covered it with a black velvet bag, and left it during many hours of the day freely exposed to the brightest sunshine. I developed the image at ten in the evening, and with perfect success. The experiment was made on one of the hottest days in the early part of July. I have made several experiments on this subject, and with the same result.

"Hence it would seem, that one special advantage in the use of the waxed paper is, that it will keep well in hot weather. It may, therefore, be confidently recommended to travellers in hot climates. For travellers, there is no photographic process, which, in respect to convenience, can be compared to the paper process; but unless the paper will keep a reasonable time when excited, the application of this process for landscapes is necessarily very limited. The traveller should be able to excite the paper over night, and walk from place to place with his camera,—take any views which he may desire, and return home in the evening to develop them. Unless he can do this, he must have his portable tent, and carry about with him all the necessary apparatus for manipulation. In certain cases, as in rambles in the East, it may be desirable, from other considerations, to have such a tent, in which calotype manipulations may be also practised; and, in such cases, the objection to the processes, in which the excited surfaces will not keep, does not so strongly apply." But, even then, it is far better, when practicable, that instead of returning from time to time to his tent for the purpose of developing, he should be enabled to take his views at once, and conduct all the developments together. A process, then, is required for travellers, especially in hot climates, in which the greatest portability of apparatus may be obtained; and where the material upon which the image is to be received will keep for a sufficient time after excitement and exposure in the camera, and without the liability to be injured or broken like glass. Now the paper process is exactly adapted to meet these conditions; and, with respect to landscapes, our efforts towards improvement should be specially directed to that process.

"As the waxed paper will keep so well after excitement and exposure in the hottest weather, it might be anticipated that, *cæteris paribus*, it would keep proportionately longer than ordinary paper under ordinary circumstances of temperature in this climate. And the anticipation generally accords, I think, with the experience of photographers. One of the best negatives I ever saw was on waxed paper; it was taken by Vicomte de Vigier a month after excitement. The scene was part of the Forest of Fontainebleau. I have also myself obtained pretty good results with the use of waxed paper excited several days previously.

"In the ordinary paper process, however, I have not succeeded in obtaining an image, worthy of being called a picture, longer than five days after exciting; though some photographers have informed me that they have obtained good pictures a considerably longer period after the exciting process.

It is not my intention to enter upon an exact comparison of the relative merits of the waxed and the ordinary paper process. As the waxed paper process is at present effected, I have no hesitation in expressing my strong predilection in favour of the old paper process for landscapes in this country, under ordinary circumstances of temperature. The long time required in bringing out the image in the waxed paper process is a serious objection—several pictures requiring many hours' attention in their developments.

"In the waxed paper process, the sky is generally obtained of a beautiful and intense black, and the limit between it and very distant objects is, generally, well-preserved. In negatives obtained by the ordinary paper process, the sky may also be occasionally obtained very black; but, in my experience, this blackness of the sky in the latter process is not nearly so uniformly attained as in the waxed paper process. Much might be said on the special conditions of weather which appear to be most favourable to the obtaining of well-defined distances in calotypes of landscapes, trees, &c.

"On the other hand, I am not quite satisfied, that in an exact comparison between a good negative on paper, such as Turner's, and a waxed paper negative, the superiority must not be ascribed to the former. From what I have seen, I should, especially in respect to beautiful gradation of tint, be inclined to say that the old paper process has the advantage. When we reflect that in the ordinary process the image is comparatively superficial, whilst in the waxed-paper process it penetrates and exists in the very substance of the paper itself, we might expect that, in regard to the quality mentioned, the former would excel the latter. In the one case, there is only the irregularity of the surface to deal with; whereas, in the other, there is the irregularity of the entire thickness of the paper itself."

M. Le Gray's Process.—Next for consideration will be the original method, as practised by Le Gray himself, with modifications by others of his successful followers. To M. Le Gray we are indebted for this and several other improvements in the calotype, and for the following modification of the wax paper process. He dissolves, in a *bain-marie* or flat iron pan, 300 grains of good isinglass, in a litre of distilled water; of the gelatine thus formed he takes about eleven ounces, to which he adds half an ounce of iodide of potassium, 120 grains of bromide of potassium, and 60 grains of chloride of sodium. When this mixture is thoroughly incorporated and filtered through fine linen, and before it is cool, he dips his previously selected paper, piece by piece nto it, withdrawing it at the end of some few minutes, when it is suspended by a corner to dry. This operation can be performed in a full light, and the paper thus prepared is said to preserve its sensibility for months.

More recent French photographers suppress the bromide of potassium and the chloride of sodium altogether, augmenting the iodide of potassium to 300 grains. At a subsequent period M. Le Gray claimed the discovery of the wax process, although it seems doubtful if he was the first who practised it; at least the following statement gives a different version of the discovery.

M. Fabre's Process.—We find in the journal *La Lumière* a highly interesting communication from this gentleman from Rome, which seems to be the first public notice of the waxed paper process. "I have long discontinued the glass in favour of a modification of the wax paper and albumen process," he says, "and with most satisfactory results. The blacks and whites are excellent, and the half tints much softer than in the other process." The writer proceeds to describe his process, which is as follows:—

Selecting the most suitable paper within his reach, a leaf, dipped in pure melted wax, is placed between two other leaves free from wax. An iron, such as is in use in the laundry, made moderately hot, is drawn over the paper, and suffices to wax the two other leaves with the superfluous wax. In this manner thirty or forty pieces may be waxed at once. To the waxed paper thus prepared albumen is applied as directed for the glass process. The coating of albumen being dry, a bath of acetic acid is applied to the albuminized side. The aceto-nitrate bath is now made use of, as in the ordinary paper process, to excite the albuminized side of the paper. The result was, as we have stated, highly satisfactory to the author of the paper.

On the publication of M. Fabre's note, M. Le Gray claimed the credit of having previously communicated the process in a paper addressed to the Académie des Sciences; however that may be, M. Fabre appears to have made the first public announcement of an application of wax paper to photography. M. Le Gray's process is as follows:—

"*First Process: To Wax the Paper.*—This process divides itself into several parts, waxing the paper being the first. For this purpose he takes the paper prepared by Lacroix d'Angoulême, or that of Canson brothers of Annonay. A large plate of silvered copper, such as is employed for the Daguerreotype, is obtained and placed upon a tripod, with a lamp underneath it, or upon a *bain-marie*. The sheet of paper is spread upon the silver plate, and a piece of pure white wax is passed to and fro upon it until, being melted by the heat, it is seen that the paper has uniformly absorbed the melted wax. When this has thoroughly taken place, the paper is to be placed between some folds of blotting-paper, and then an iron, moderately hot, being passed over it, the bibulous paper removes any excess of wax, and a paper of perfect transparency is obtained.

"*Second Process: To Prepare the Negative Paper.*—In a vessel of porcelain or earthenware capable of holding five pints and a quarter of distilled water, put about four thousand grains of rice, and allow them to steep until the grains are but slightly broken, so that the water contains only the glutinons portion. In a little less than a quart of the rice solution thus obtained, dissolve—

Sugar of milk	620 grains.
Iodide of potassium	225 ,,
Cyanide of potassium	12 ,,
Fluoride of potassium	7 ,,

The liquid, when filtered, will keep for a long time without alteration.

"When you would prepare the paper, some of this solution is put into a large dish, and the waxed paper, sheet by sheet, is plunged into it, one over the other, removing any air-bubbles which may form. Fifteen or twenty sheets being placed in the bath, they are allowed to soak for half an hour, or an hour, according to the thickness of the paper. Turning over the whole mass, commence by removing the first sheet immersed, and hooking it up by one corner with a pin bent in the shape of the letter S, fix it on a line to dry, and remove the drop from the lower angle by a little bundle of blotting-paper. M. Le Gray remarks that French and English paper should never be mixed in the same bath, but prepared separately, as the 'English paper contains a free acid which immediately precipitates an iodide of starch in the French papers, and gives to them a violet tint.' The paper, being dry, is to be preserved for use in a portfolio; even in this state it is not absolutely insensible.

"*Third Process: To render the Waxed Paper Sensitive.*—Make a solution of

Distilled water	2325 grains.
Crystallized nitrate of silver	77 ,,

and when this is dissolved add of

Crystallized acetic acid	186 ,,

"Papers prepared with this solution will keep well for a few days. M. Le Gray, however, recommends for his waxed paper, and for portraits, that the quantity of nitrate of silver be increased to 155 grains; the paper must be used moist.

"The method of preparing these papers is to float upon an horizontal plate of glass either of the above solutions, and taking a piece of the iodized paper, to carefully place it upon the fluid, taking great care that no air-bubbles interpose. The paper must remain a short time in contact with this sensitive fluid until chemical combination is effected. Four or five minutes are required for some papers, and eight or ten seconds are sufficient for other kinds. When a violet tint appears the paper should be removed.

"For those papers which it is desirable to keep for some time, as during a journey, it is recommended that into one vessel of porcelain you put about five or six millilitres of the strong aceto-nitrate above described, and into another some distilled water; plunge completely both sides of the waxed and iodized paper in the first fluid, and allow it to remain about four or five minutes; withdraw it, and plunge it immediately into the bath of distilled water, in which let it soak for not less than four minutes. When these papers are carefully dried they may be preserved for some time for use, and by lessening the dose of nitrate of silver this period may be considerably prolonged. It will, of course, be understood by all who have followed the processes described up to this point, that the papers which are prepared for keeping are not those which are the most sensitive; hence it is necessary to expose them a much longer time in the camera than those prepared by the stronger solution of silver. The more sensitive paper, under ordinary circumstances of light, will require an exposure in the camera of about twenty seconds, the less sensitive demanding about ten or fifteen minutes, according to the circumstances of light.

"*Fourth Process: The Development of the Image.*—The picture is developed by the aid of gallic-acid dissolved in distilled water. Le Gray finds the following to be the best proportions:—

Distilled water	40 fluid ounces.
Gallic acid	60 grains.

"The paper is to be plunged into this solution, and allowed to remain until it is fully developed. The time will vary from ten minutes to two hours, or more, according to the intensity of the rays incident on the paper when in the camera. The development of the image is much accelerated by the addition of fifteen or twenty drops of the aceto-nitrate of silver.

"*Fifth Process: Fixing.*—It is often found convenient, when on a journey, to give a temporary fixedness to the pictures obtained, and to complete the process with the hyposulphite at any time on your return home. A wash of 360 grains of bromide of potassium to two quarts of water is the strength which should be employed. The process of fixing with hyposulphite consists, as in other preparations, simply in soaking the paper until the yellow tint of the iodide has disappeared."

The reader cannot do better than study the conclusions arrived at by Mr. W. Teasdale, as the results of a number of carefully-performed experiments on the wax-paper process, and which he has put in a tabular form, for the more easily comparing one process with another. After enumerating the peculiarities which give the practice of the paper processes advantages in many respects over the Daguerreotype, the collodion, and the albumen processes, he proceeds to the consideration of the employment of waxed paper as a prominent modification. The value of the wax depends not merely on its filling up the pores and producing a uniform surface, but on its giving greater transparency, strength, and a tenacity, which is very advantageously experienced in the washings. He considers, also, that the pictures are more free from spots or stains.

"*Paper.*—The choice of paper (Mr. Teasdale says) is of less importance than in the ordinary calotype process. The texture should be uniform, and the sizing wholly organic. Whatman's, Turner's, and other papers made in England, though smooth, firm, and of even texture, are all sized with gelatine (glue), which not only has a tendency to retard photographic action, but renders the paper so dense, that the author has found it necessary to soak it in warm water and dry it before waxing. They also curl up strongly when floated on one side; are less transparent, so that air-bubbles are more readily overlooked in the exciting and other operations; they do not assume the desirable violet tint after iodizing, and the finished negative prints very slowly. Some of these papers, however, seem to bear prolonged development better than the French. The papers of Canson, Lacroix, and other French makers, are almost wholly sized with starch; this increases their sensibility, and is readily permeable by the wax. Though very thin, these papers are remarkably tenacious; but the texture, especially of the 'Lacroix' and 'New French,' is not exactly all that could be desired. The principal defect in Canson's is the presence of minute particles of metallic substance, which, unless removed by the process hereafter described, or some other, produce spots and spoil the beauty of the negative. The paper preferred is what is known here as 'New French,' the only defect of which is the texture, which does not allow of the sharpness of outline required by the architect or engineer; but this would doubtless lead the artist to prefer it.

"*Waxing.*—A cheap and easy method is to employ a thick oven-shelf, which, when once heated, will be available for a considerable number of sheets. On this is placed a clean sheet of common tin plate, which must be used for this purpose alone, and kept carefully wrapped in paper when not in use. Each sheet of paper is to be laid on the tin plate, and rubbed over with a piece of wax; the perfect penetration of the paper may then be assisted by rubbing with an ivory paper-knife or the handle of a tooth-brush. The author employs the economical and easily-regulated heat of a number of gas-jets, over which the plate stands on a common kitchen trivet. When the requisite number of sheets have been waxed, they are ironed separately in blotting-paper; not, as is usually directed, to extract as much as possible of the wax, but to remove only as much as is necessary to produce a smooth surface.

"*Iodizing.*—This operation is of the first importance. It is therefore desirable to consider the photographic effect the various substances are calculated to produce.

"*Rice-water* is commonly recommended as the vehicle, on account of the starch it contains; it is useful for unsized or previously washed papers, but for French papers, which usually contain an excess of starch, the author prefers pure water, especially if the solution contains organic substances, such as sugar of milk, albumen, &c., in addition to the alkaline salts.

"*Iodide of Potassium.*—The quantity recommended by Le Grey and others is far too small, unless thick paper is used and the light is strong. To obtain intense blacks and graduated shades on French papers, the author at least doubles the quantity, unless operating under a bright sunny sky.

"*Bromide of Potassium.*—Using achromatic lenses, the author employs a small quantity of this salt, which accelerates the effect by its peculiar sensitiveness to certain rays, but if much bromide is added the paper is rendered slow; however, if insufficiently exposed, it bears prolonged development without injury to the whites of the negative. It is probably the large proportion of this salt in the Vicomte Vigier's solution, that renders papers prepared with it capable of retaining their sensibility so long.

"*Cyanide of Potassium* the author was long opposed to, on account of its retarding effect and the reduction of intensity; but these disadvantages are more than compensated by its penetrating the wax so readily, taking from it the greasy appearance, facilitating the saturation with the other salts, preserving the whites, and rendering the negative cleaner and more transparent.

"*Fluoride of Potassium* the author uses in small quantity, like many other persons, solely on the authority of the French operators, who attribute to it a power of increasing the sensibility greatly, which no one seems to deny.

"*Chloride of Sodium*, used sparingly, is a valuable agent in giving intensity to the blacks, and slightly increasing the sensibility; if in excess, great care is requisite to prevent solarization.

"*Organic Substances.*—With the exception of the starch sizing, sugar of milk is the principal; like other matters of the same class, it facilitates the reduction of the metallic salts, gives dense black skies, and modulates the tones of the pictures. The author uses a small quantity of honey, because continental photographers state that it increases the sensibility; probably the use of gum arabic, as recommended by Mr. Ramsden, answers the same purpose. White of egg (albumen) is commonly used, without any particular reason being given. The author employs it simply for the sake of improving the appearance of the finished negative, to which it gives a slight gloss. Mr. Fenton thinks it renders the paper slower. Isinglass is used only by Le Gray. The author does not attribute any advantages to it, and finds it renders the solution so thick and glutinous that air-bubbles can scarcely be avoided.

"*Iodine.*—By far the greatest improvement in all the iodizing solutions is the addition of free iodine in considerable quantity, as suggested by Mr. Crookes. This certainly has the power of removing metallic specks from the paper; and as the iodized papers have, before being excited, a dark purple colour, the presence of an air-bubble cannot escape detection, and the process of exciting is rendered easy and certain. If the solution contains any cyanide of potassium, a much greater quantity of free iodine will be required than when none of this salt is present.

"*Exciting.*—It is stated by Mr. Hunt, that when iodide of silver is made by mixing solutions of nitrate of silver and iodide of potassium, the more dilute the original solutions are, the more sensitive will the precipitated iodide be. The author's experiments confirm the doubt this raises as to the truth of the common opinion, that the sensibility of the paper is in direct proportion to the strength of the silver solution; and he employs a weak solution of nitrate of silver, using a proportionately larger quantity of this solution, whereby (he thinks) the manipulation is rendered easier, and the sensibility greater and more equal over the whole sheet.

"With the view of increasing the sensibility of papers not required to be kept long, the author has tried the effect of exciting solutions containing less acetic acid (generally fifteen grains of glacial acetic acid to every ten grains of nitrate of silver in the solution) than is recommended by Le Gray and others; but has had more failures from this cause than from any other, the pictures becoming brown in the development, especially if long continued.

"The method employed to prepare, say six or eight sheets, is as follows:—Upon a large piece of plate glass levelled by screws, are poured four drachms of a fifteen-grain solution of aceto-nitrate of silver; the marked side of a sheet of iodized paper is floated upon this, prevented from curling up by breathing gently on it, and carefully raised at each corner to see that every part of the under surface is wetted. It is allowed to remain untouched for four or five minutes after the last traces of colour have disappeared from the upper surface, which must be preserved from contact with the solution, to avoid the probable production of black spots on the back. Removed from the silver solution, the paper must be floated for a few minutes upon a pint or so of water (which will serve for the whole six or eight sheets), holding the sheet by the corner and slightly agitating it. Then it is pinned up to dry, without blotting off, merely attaching a morsel of blotting-paper to the lower corner to assist the rapid draining away of the liquid. If the upper corner is dried by pinching it between the thumb and finger, silver pins need not be used, as then no liquid will run down. For every fresh sheet, add about two drachms of fresh aceto-nitrate solution to that on the glass plate, and proceed as before. When the sheets are all excited, pour the aceto-nitrate remaining on the plate into a separate bottle for use in the development; the quantity barely sufficing, none is wasted except what is lost in the washings, and this may be recovered if thought worth while. It may be better, but is by no means necessary, to use distilled water or filtered rain-water for washing. The water used by the author is well-water, containing salts which precipitate silver, but he finds no difference in the result, whether he uses this or perfectly pure water.

"It is convenient, for many reasons, to use one standard size of paper, such as a quarter-sheet, 11 × 9 inches, for a 3¼ lens, or a sixth, 9 × 7½ inches, for one of 2¾ inches diameter. The latter is always used by the author.

"It is a generally received opinion that in iodizing the sheet, the maximum of sensibility is attained at the moment when the last trace of violet or purple colour vanishes, and that it then begins to diminish, unless the paper is removed. The author considers this to be erroneous; he believes the paper only attains its maximum of sensibility several minutes after the colour disappears, and that the sensibility is not diminished if the paper is left five, ten, or fifteen minutes longer on the exciting solution.

"*Exposure.*—The requisite time of exposure depends on so many circumstances—the lens, the diaphragm, the season, weather, hour of the day, character of view, &c.—that no safe general rule can be given. Perhaps for a landscape in diffused light, in fine clear weather, an average of twenty minutes with a Ross lens two and three-quarters inches, and a half-inch diaphragm, will be about the best. With paper used wet, as in Flacheron's process, probably three or four minutes would suffice; but the whole manipulation would then be different, and the view must be taken and developed soon after exciting. The author cannot state how long his paper might be kept after exciting. Sheets kept eight or ten days in autumn had not lost much; requiring perhaps five minutes longer exposure.

"*Developing.*—It is best to prepare gallic acid in a quite saturated solution, four ounces of which should be poured into the dish and one ounce of pure water added. When thoroughly mixed, the marked side of the negative is to be floated on it, breathing on the back slightly as in exciting, for the same reason; it should be left five or ten minutes at least before adding any aceto-nitrate, and if the operator has not time to watch the development and arrest it at the right moment, the picture may be safely left for many hours floating on the gallic acid solution; this, if the picture has been over-exposed, will be the best method to prevent its being spoiled by solarization. In either case, when the operator has time, the negative should be taken from the dish with one hand, while with the other the two or three drachms of the refuse aceto-nitrate solution above mentioned should be added and well mixed, and the negative then replaced upon it. The time required to develop the image will enable the operator to judge whether an additional quantity of aceto-nitrate should be added. When the image is fully brought out, drain off the developing liquor, pour clean water into the dish, changing it once or twice, then turn the negative face upward and brush it with a camel's-hair pencil kept expressly for this purpose. If not convenient to fix it at once with the hyposulphite of soda, it may be kept for a length of time, along with others, in a portfolio.

"Considerable latitude is allowable as to time of exposure, as error in this respect may be counteracted subsequently. If too short, so that in the longer development required the picture turns brown and will scarcely print, the transparency may be restored without injury to any of the blacks, by immersion in a dilute solution of cyanide of potassium, about sixty grains to one pint. This will sometimes remedy solarization also. If the development has been arrested too soon, the fixed and finished negative may be improved by floating it on a solution of chloride of gold, such as is used for giving a deep violet tint to positives.

"The reason for floating the negative and developing on one side only, is to preserve the cleanliness of the picture, and to prevent the stains and marbling often arising from dirty dishes; the black deposit formed during the long development sinks to the bottom of the dish, and is never touched by the floating negative. Le Gray recommends acetic acid for removing stains and spots, but the author does not find this agent available, while the partial use of cyanide of potassium, which alone produces the effect, spoils the beauty of the negative."

I may here remark that, to amateurs generally, one of the most annoying causes of failure in the wax-paper process is the marbling appearance which occurs with some of the most beautiful negatives, and spoils them as perfectly as if they were soaked in ink. This arises from the use of dirty dishes for the various solutions, particularly those for the nitrate and gallic acid baths, but more especially the latter. Even though they may seem clean, and though the picture is not even allowed to touch the bottom of the dishes, the marbling may show itself in the picture during development. To insure perfect cleanliness, then, which is more necessary in the waxed paper than in any other photographic process, the dishes should always be thoroughly washed and rubbed dry with a clean cloth, both before and after use, and a separate dish should be used for each solution. In this, and in all the other photographic process, it is almost an impossibility to be *clean enough*, therefore never spare clean cloths and plenty of water, and having once put the sheet of waxed paper into either the exciting or developing dish, never take it out again, or lift it without previously skimming the surface of the liquid; this is done by means of a strip of blotting-paper held by each hand, and drawn along the surface, edge down.

The following, being Mr. Teasdale's Table of Comparison, may be useful to the photographer.

TABLE OF THE WAXED PAPER PROCESS.

Iodizing Solutions.

Vehicle.	I. Le Gray.	II. Pulch.	III. Vigier.	IV. Fenton.	V. Ramsden	VI. Crookes.	VII. W. Hunt.	VIII. Teasdale.
	Rice water.	Distilled water.	Boiled whey.	Either distilled or rice water.	Rice water.	Distilled water.	Rice water.	Distilled water.
Iodide of potassium	120	140	220	350	90	480	120	240
Bromide	......	8½	35	10	......	......	70	20
Cyanide	6	8½	17	17	......	......	......	8
Fluoride	3¾	4¼	13	8½	......	......	48	10
Chloride of sodium	......	......	......	26	......	......	70	10
Sugar of milk	360	132	......	350	240	......	160	240
Honey	......	88	......	44	......	......	......	50
Albumen	480	480	480	480	......	......	......	480
Isinglass	120 ?	......	......	......	......	......	......	......
Gum-Arabic	......	......	......	......	50	......	......	......
Free Iodine.........	1 or 2	......	......	sherry colour.	nearly a port wine tint.	sherry colour.	ad libitum.	deep port tint.

Exciting Solutions.

Nitrate of silver...	32	......	......	32	35	15	10 or 12 used wet	15
Gl. Acet. Acid ...	36	......	......	36 (less if to be kept longer.)	35	16	——— ?	20 to 25

"*Remarks on the Table.*—I. The large proportion of organic matter in M. Le Gray's solution, renders it too thick and glutinous. The albumen represents one ounce, or the white of a single egg, expressed in grains to preserve uniformity, and to facilitate comparison of the proportion of organic substances in each solution. The small proportion of iodide is not suited for thin paper; it however possesses the advantage of sustaining uninjured the prolonged action of the developing agent better than many others.

"II. Mr. Pulch's solution is very sensitive, but does not keep well; and turns brown if the development be continued too long.

"III. Viscount Vigier's solution will keep uninjured, after exciting, longer than any other (say in winter six or eight weeks), but is very slow in its action.

"IV. Mr. Fenton's solution is very good, especially for the thin old Canson's paper made some years ago.

"V. Although I have not been very successful in using Mr. Ramsden's solution, it has produced, in other hands, the best negatives I have ever seen. It would be better, I think, to double the quantity of iodide.

"VI. Mr. Crookes' solution has given me one or two good pictures, but requires at least the addition of some organic matter, such as sugar of milk or rice water.

"VII. Mr. Hunt has given this solution as the result of a connected series of carefully made experiments on the use of the bromides; but it is to be regretted that he used common meniscus lenses, in operating with which I think the peculiar value of the bromides is not apparent.

"VIII. I have been led to adopt my own iodising solution for general use from experiments with, and consideration of most of the preceding."

M. Geoffroy's Process.—Before leaving the wax paper for the present we shall devote a few minutes to the consideration of a new method of preparing waxed paper, by M. Stephane Geoffroy, of Roanne:—

"1. M. Geoffroy places 500 grammes (about eighteen ounces avoirdupois) of yellow or white wax, and one litre (about a quart) of alcohol of commercial strength in a glass retort, and boils the alcohol until the wax is completely dissolved, having previously attached a receiver to the retort to collect all the products of distillation, he then pours the still fluid mixture into a glass vessel, and as it cools the myricine and cerine solidify, while the ceroleine remains in solution; this liquid is separated by passing it through fine linen, and, as a final operation, mixing it with the alcohol which passed over in the distillation, and filtering it through paper in a glass funnel. A store of this liquid is kept in a carefully stoppered bottle, to be used as required in mixture with the following.

"2. He then dissolves in 150 grammes (about five ounces) of alcohol of 36° twenty grammes (five drachms Apoth. W.) of iodide of ammonium (or potassium), one gramme (about fifteen grains) of bromide of ammonium or potassium, and one gramme (about fifteen grains) of fluoride of potassium or ammonium.

"Taking a capsule he pours drop by drop upon about one gramme (about fifteen grains) of iodide of silver freshly prepared, as much of a concentrated solution of cyanide of potassium as is required to dissolve it.

"This dissolved iodide of silver he adds to the preceding mixture, and agitates it; there remains at the bottom of the bottle a rather thick deposit of all the above salts, which serves to saturate the alcohol, with which that already saturated is successively replaced, and removed in the manner and proportions to be described.

"3. These two bottles being ready, when about to prepare negatives, he takes about 200 grammes (six and-a-quarter ounces Apoth. W.) of the solution No. 1, of ceroleine and alcohol, with which he mixes twenty grammes (five drachms Ap. W.) of the solution No. 2. Filtering the mixture with care, to avoid undissolved crystals, which spot the paper, he makes a bath in a porcelain dish, wherein he soaks for about a quarter of an hour, five or six at a time, papers previously selected and cut to size; continuing to do so until the solution is exhausted. Taken out, hung up by a hook in one corner and dried, these papers, which have acquired a very uniform rose tint, are covered up from dust and kept dry. In rendering them sensitive with nitrate of silver, developing with gallic acid, and fixing the proofs with hyposulphite of soda, the ordinary method is followed—generally that of M. Le Gray—adding one or two grammes (fifteen to thirty grains) of camphorated spirit of wine to one litre (about one quart) of the solution of gallic acid."

The great advantages M. Geoffroy found in preparing his negatives by this method are as follows:—

"All who use paper waxed by M. Le Gray's process, are aware of the slow and difficult preliminary operations required previous to rendering it sensitive with nitrate of silver. They know how much precaution is required to obtain paper uniformly coated and unspotted, in the midst of such long operations, where the chances of accident are so numerous, the constant attention required to guard against the impurities of the wax of commerce, against dust during the impregnation of the paper and the ironing, against too great heat in the latter, and against bad quality of the paper used for absorbing. Photographers also know how much wax is lost in this process, and what the quantities of paper necessarily cost in absorbing properly. The difficulty and tediousness of the imbibition of an aqueous solution by paper previously waxed is equally known. On the other hand, by the method here described, the iodizing and waxing are effected in one simple and rapid operation; the imbibition is, as may be imagined, very uniform and complete, from the facility with which alcohol penetrates; and that granular appearance which is so troublesome in ordinary waxed proofs, is avoided by this method, owing to the character of the ceroleine—this substance possessing elasticity in a remarkable degree.

"The solution of ceroleine in alcohol is moreover very easily prepared, and comparatively cheap, for the residues of stearine and myricine may be either sold or used with excellent effect for waxing fixed proofs.

"The solution made by the above formula is photogenic in a very high degree; indeed, when used with either thin or thick papers, it gives, from the first bath of gallic acid, blacks of an intensity which it is impossible to obtain with Le Gray's paper, and, which other papers scarcely acquire after having been treated a second time with acetic acid or bichloride of mercury. At the same time, they preserve the whites and half-tints in a manner which surprised me. The transparency of the proofs is also admirable, and the clearness of the image yields in nothing to that of proofs obtained upon albumen."

Lespiault's Process.—The following process by Lespiault is considered useful in some cases, and is very easily prepared; but I cannot personally speak as to its merits, not having tested it:—

"The prepared papers do not," says M. Lespiault, "keep very long in the hot season; but if they are sensitized in the morning, or even overnight, they will keep the whole day if care is taken to wash them in three fresh waters. I am speaking of the papiers Saxe, the only sort that I habitually use. Turner's keeps much better, but it is only half so rapidly sensitized. This is the formula for the preparation of the iodide :—

Eau de vie, from 18° to 20° .	500 grammes (16 ounces).
Sugar of milk . .	to saturation.
Iodide of zinc . .	10 grammes (150 grains).
Bromide of zinc . .	2 grammes (30 grains).

"The quantities of iodide and bromide indicated above may also be dissolved in 250 grammes (8 ounces) of distilled water; saturated with sugar of milk; and 250 grammes (8 ounces) of alcohol added to this solution.

"The papiers Saxe immersed in this liquid for four or five minutes take a very even rose tint in drying. The paper can be kept in this longer without any bad effect.

"These papers, once dry, will keep indefinitely; when it is wished to sensitize them, float them on a bath of aceto-nitrate of silver of five per cent. with the addition of from seven to eight per cent. of glacial acetic acid.

"The paper becomes little by little very white; at the end of four or five minutes, when the tint is very equal, it is taken out, and immersed in a bath of distilled water: this should be renewed three times, allowing a quarter of an hour between each time, and dried afterwards with blotting-paper, and the operations continued the same as with the wax-paper.

"If the bath of aceto-nitrate were more concentrated, by ten per cent. for example, the paper would not keep, and the print would want delicacy; if it were weaker it would be liable to unsensitized patches, or it would be necessary to keep the paper much longer in the liquid. This observation applies, I believe, to all negative papers, and, above all, to those which are not waxed.

"Using a lens of three inches in diameter, fifty centimetres (about thirty inches) of focal length, with a diaphragm of fifteen millimetres, a quarter of an hour's exposure, instead of thirty-five minutes, is sufficient for photographing an old building or a street. Trees can be taken in the same space of time, if a diaphragm with an opening large enough is employed, but, with the same diaphragm, it takes forty minutes. It takes an hour and a-half with waxed or albuminized paper. I attribute this enormous difference in rapidity to two causes: first, to the different bases of the iodides; and, secondly, to the absence of any fatty substance, such as wax, which retards more or less the formation of the image. If the paper has not been altered by the heat and the remains of the nitrate which [has not been removed by the washing, the whites can be preserved two hours in the bath of gallic acid. The prints so obtained are delicate, and without roughness; and the blacks are always sufficient when the time of exposure has been suitable."

In conclusion, I must say that half the failures result from *impure wax*. The fact is well known that the white wax generally sold as purified wax *is more than half adulterated* with *foreign substances*; here we have a cause of failure to be only got rid of by going to a respectable wax-bleacher, and telling him for what purpose the wax is required. Another cause of failure or *graining* in the negative, although that just mentioned is the greatest, is using the iron too hot when waxing. More than half the success of the wax paper process depends on the perfect manner in which the paper is waxed and the purity of the wax employed.

Summary.—Having given, in the preceding pages, the different formulæ of some of the most eminent and successful operators; it now remains to give the reader some practical observations on the manipulatory portion of the information already conveyed. To begin, then, with the beginning, the first subject for examination will be the causes of failure in "THE CALOTYPE PROCESS."

The causes of failure in the calotype, as in *all* the other branches of photography, are numerous; and, I am sorry to say, in reference to the science in general, that the causes of these failures are nearly always to be traced to the inattention, carelessness, or *dirty habits of manipulation*, in the operators. I say *dirty habits*, for there is nothing so easily acquired, *or so difficult to get rid of*, as a slovenly, dirty, method of manipulation. As an instance, I had a friend—in fact, a pupil—some short time back, who was constantly writing to know the cause of this failure and of that. Now, he was remarkably clean and neat in his habits and person, so much so that I never for a moment thought, after I first mentioned the subject, that his failures could arise from any want of care in that direction, and I was fairly puzzled to account for some of them, knowing that his chemicals and apparatus were of the first quality. At last I determined to pay him a visit. I found that he had gone to some degree of expense as an amateur in fitting up a glass-house, dark-room, &c.; and could plainly see that it was not from want of expensive materials, or persevering trials, that he failed; so I said to him, "Well, I have come to see you work; so commence as soon as you like—I shall be your sitter." He commenced in a first-rate style of activity, took up a glass plate (he was working the collodion), picked up a piece of old linen that was lying on the developing bench in his dark room, with which he polished his glass, coated it, and plunged it in the bath. He then proceeded to arrange and focus me; he had a curtain over a beam, for the purpose of shading one side of the face, and in his usual energetic manner he gave this curtain a pull, in order that he might place it where he wished, and drew it suddenly along the beam (which I am sure had a month's dust on it), and set a cloud floating about the room that would take at least three hours to clear away. He then put the plate in the camera, and, after exposing, he took up the glass holding the developing solution from out of a mess of wet, &c.; and, in pouring the developing solution on to the plate, he let a couple of drops fall on the latter from the bottom of the developing glass, furnished by some of the indescribable mess in which it had been previously standing. Considering this, and also that the atmosphere in which the plate was taken out of the bath was saturated with dust, and the state of the interior of the camera in which it was exposed, recollecting, at the same time, that the cloth with which he wiped the glass was taken off the sloppy bench, it is not to be wondered at that the resulting negative was somewhat similar to the first effort of a schoolboy in drawing a portrait over which he subsequently upset his ink. "There, sir," says he, "how do you account for that?" I said at the time, wishing to see if he would go on in the same way, "Well, I scarcely know; try again." Everything was repeated exactly as in the first instance, with this addition—he actually washed his glass in the water which had just washed the hyposulphite of soda off his last picture!

I then told him to get his curtains taken down and dusted, his beams and floor washed out, his dark-room well scrubbed, and a small shelf put up for his developing glass, covered with half-a-dozen thicknesses of blotting-paper, his cloths well washed *without soap*, a few nails put up on which to hang them, one to be kept for cleaning out the slide (or, what is better, some papier Joseph), another for wiping the glasses after washing, and a third for polishing them, strict care being taken that there should be no dust or slop of any kind; and the result was, that he has never had occasion to write to me since. Now, what holds good with collodion holds good with every other branch; it must be always borne in mind that the greatest care, the strictest cleanliness, and the most undeviating perseverance, are necessary to the successful practice of photography.

And now, then, to return to what I commenced with—the causes of failure in the calotype process.

Causes of Failure.—If the negative in developing assume a disagreeable reddish or foxy brown, the cause, probably, is a deficiency of acetic acid in proportion to the strength of the silver used, or from the presence of nitrate of potash left in the paper; by not washing the iodized papers sufficiently, or from not using a sufficient quantity of water for the removal of the salt named. It may also arise from not using the iodized paper for a considerable period after it has been prepared. It must be noted, that the sooner the iodised paper is used after preparation, the more brilliant and satisfactory the picture will be.

Remedy.—After well washing the negative, when fully developed, and before submitting it to the fixing bath, immerse it in the following solution until the required black tone is acquired. Take

Chloride of gold, 1 drachm.
Distilled water, ½ pint.

Hyposulphite of soda, 3 drachms.
Water, ½ pint.

When dissolved, stir the water, and, stirring all the time, add the chloride of gold solution in small portions at a time. This bath will convert the foxy red colour of the negative into pure black, and it must be afterwards fixed in a solution of four parts water and one part hyposulphite of soda; after which it must be well washed in plenty of water. Perhaps it may be necessary to explain what I mean by well washed. Place your photograph in a shallow dish under a water tap, and turning the tap so that you may have a stream about the diameter of a good-sized quill, allow it to run over your photograph for three or four hours; after which hang up to dry. I should then consider the photograph sufficiently well washed.

Spots and Stains, showing the grain of the flesh in the points of the fingers. These are invariably caused by carelessly allowing the fingers to come in contact with the paper when preparing it, more especially when making it sensitive in the nitrate of silver bath, or in any part of the process when the fingers have been dabbling in hyposulphite of soda previously.

Remedy.—Keep the fingers particularly clean, and never touch the surface of the paper at all; handle it by the corners in every operation.

A Black Uneven Line, running from one corner in the direction of the opposite one. This is caused by the use of a brass pin, for the purpose of pinning up the sheet by one corner; it partly reduces the silver, and the combined solutions running down in the direction of the lowest corner causes the stain.

Remedy.—Carefully wipe your pins, and before you pass them through the papers blot off the corner to be pinned, and double a piece of blotting-paper over the corner before you insert the pin. This is more necessary when using the silver solution than at any other time.

Blackening in the Bath.—The negative will blacken all over in the developing bath. This may be caused by over exposure, but in that case there will be a feeble image of the object on the negative; or it may be caused by light getting entrance to the camera independent of the lens; or the prepared sheet may have been accidentally exposed to the light previous to development.

Remedy.—Should the universal blackening be caused by accidental light, remedy the defect; if caused by over exposure, expose for a shorter time.

The Negative will become red, or foxy all over. This arises from the want of sufficient acetic acid to regulate the decomposition of the silver salt, and keep it in such a state that it can only be decomposed by light.

Remedy.—Increase the quantity of acetic acid. Acetic acid differs very much in its strength, therefore any quantity mentioned in this treatise means that quantity of glacial acetic acid.

Woolly Appearance.—A woolly rough appearance in the negative, which of course would be worse in the positive; this may arise from too much washing when the paper was iodized—a paper too rough in its texture—using a rough grained blotting-paper after exciting—or using paper that has been iodized for a very long time. It may also occur from want of proper focusing, or the agitation of the camera during exposure from wind, or other causes. As it would be impossible for me to say which of the above would cause this appearance in any particular negative without seeing it, I can only point out the cause of the effect to the reader, leaving it to him to ascertain what the particular cause may be, and then he can easily remedy it himself if he has carefully considered the principles involved.

White or Black Spots, with streaks from them. These are nearly always caused by the most minute particles of iron, copper, or brass, getting into the paper either accidently or from the wear and tear of the machinery used in making it, of course there is no remedy for these but to choose paper quite free from them.

Marblings do not appear until after the first or second preparation of the paper, when spots of irregular form, markings of a dozen shapes, *all* arise from want of care, either in not skimming the surface of the developing or exciting solution, when immersing or lifting negatives into or out of it, or not thoroughly washing and cleaning the dishes or measures used, especially when one dish or measure has to receive two or three solutions, or from not properly cleaning the glass against which the paper is pressed in the paper slide, or from other similar causes.

Remedy.—More care and attention to cleanliness. Let me again impress on the operator the necessity, if possible, of keeping separate dishes and measures for each solution; and even then wash and clean them, as if they had contained solutions of a different nature.

Causes of Failure in the Wax Process.—Almost all the observations made with regard to the calotype relate also to the wax paper process; but the use of *wax* as a preliminary preparation necessitates a few additional observations. In the calotype many of the *causes* of failure—I mean more particularly the woolliness of the negative—cannot be traced to the same causes in the wax paper process; for instance, the washing or blotting off with rough paper, because the first operation in the latter process is to fill the pores or body of the paper with wax; this paper, of course, will stand all the washing and blotting you may wish to give it, as the presence of the wax renders it hard and smooth on its surface. But similar effects may be caused by the adulteration of the wax,—a thing so common that, unless you go to a first-rate establishment (and that *must be* a wax bleacher's), you cannot obtain a pure specimen; even in the last case, you must tell the principal for what purpose you want it; but the wax you will then obtain *will not be white*. The principal substance of adulteration is spermaceti, and the woolliness or roughness is owing to the unequal action of the chemicals on the atoms of wax and spermaceti. Another great cause of unequal action arises from using an iron *too hot*, as in that case it *removes the wax*, and that unequally. These few observations, added to the foregoing, will be quite sufficient. I would have the reader bear in mind that, although the surface of waxed paper is not so easily damaged by washing as the prepared paper, still it will be well to prevent any friction; it is, therefore, better to float or immerse the papers in the different solutions than to use the glass rod; the finest-grained *blotting-paper* should also be used.

PHOTOGRAPHY ON GLASS.

The Albumen Process.—The art is indebted to Sir John Herschel for the adaptation of glass plates to receive sensitized organic substances. In order to determine how far organic matter was indispensable to the discoloration of silver solutions, he prepared a solution of salt, extremely diluted, which he mixed with nitrate of silver, so dilute as to form together a liquid only slightly milky. This was poured on a plate of glass laid horizontally at the bottom of a flat vessel, from which, after several days, the liquid was drawn off by a syphon tube, and the last portion, drop by drop, by a syphon composed of a few fibres of hemp laid parallel, and moistened without twisting. The glass was not touched till quite dry, when it was found coated with a uniform film of chloride of silver, which adhered with considerable tenacity to the glass, but was not sensitive to light. On dropping on it a solution of nitrate of silver, and spreading it over by inclining the plate to and fro, it became highly sensitive. Exposed in this state to the focus of a camera, it became impressed with a remarkably well-defined negative picture. These experiments, communicated through the Journal of the Royal Society, had no doubt their influence on the ardent minds who were then pursuing this wonderful and fascinating art.

Among others who had devoted themselves to the investigation was M. Niepce de St. Victor, the nephew of the discoverer of the Daguerreotype process. This gentleman, as early as 1847, had made considerable progress in developing the albumen process, and seems fairly entitled to the merit of perfecting the idea thrown out by Sir John Herschel. However that may be, from that date the use of glass was rapidly brought to perfection. This process derives its name, our readers need scarcely be told, from the organic substance chiefly used, namely, the white of eggs. Albumen forms one of the constituents of many animal substances; amongst others, and in combination with different fatty matters, it is found in its purest state in the white of an egg.

Mr. J. E. Mayall has entered so very fully into this process in his address to the Photographic Society, that we cannot do better than quote his paper. "Albumen," Mr. Mayall proceeds to say, "is the true starting-point from which all animal tissues are formed, as the egg contains no other nitrogenous compound except albumen; the yolk containing, besides albumen, a yellow fat only. Its chief characteristic is its coagulability by heat. We shall speak of its two conditions,—soluble, or uncoagulated albumen, and insoluble, or coagulated albumen.

"*Soluble Albumen.*—Animal albumen of the soluble kind may be obtained in a solid form by evaporating at a temperature below 120°; it is then a dry, yellowish, horny, and brittle mass.

"This can be powdered, and treated successively with ether and alcohol, which free it from fat, salts, and other foreign matter, until we obtain it pure.

"When thus completely dry it is without taste or odour, and has neither acid nor alkaline reaction.

"In the dry state it may be heated even to the temperature of boiling water, without passing into the insoluble coagulated form. Moistened with water, it swells up, becomes transparent, and by the addition of more water it dissolves into a colourless, tasteless fluid.

"If this solution be heated to a temperature of 140°, it passes into the coagulated form. Less concentrated solutions require a heat of 160°, and very dilute solutions require even boiling before the albumen will coagulate.

"Albumen is insoluble in alcohol and ether. It is soluble to a certain extent in distilled water, but much more easily in water that contains an alkaline salt or chloride of sodium.

"Mulder has given great attention to its analysis. His most recent investigation gives:—

Carbon	53·5
Hydrogen	7·0
Nitrogen	15·5
Oxygen	22·0
Sulphur	1·6
Phosphorus	0·4
	100·0 parts.

"Albumen easily putrefies in the moist state, by the action of the atmospheric agents, for which reason it requires to be used immediately after it is mixed with the chemicals; in winter the time may be prolonged to forty-eight hours, but in summer not longer than six hours.

"The greater number of the metallic salts, according to Lehmann, precipitate albumen, the precipitate containing either a combination of basic salt with albumen, or a mixture of two compounds, one of which consists of the acid of the salt and albumen, and the other of the base of the salt and albumen. The albumen generally passes into the insoluble form.

The precipitated and washed albumen, when dissolved in $\frac{1}{200}$ of caustic potash, and digested for one hour at a temperature of 160°, converts the sulphur and phosphorus into a phosphate and sulphide. The filtered solution, if now treated with acetic acid in slight excess, yields a gelatinous precipitate of protein; which Mulder, its discoverer, designates as the basis of albumen, fibrin, and casein.

"For the object of this inquiry it is sufficient to know, that albumen cannot exist in the soluble state in the absence of mineral constituents; that a slight alkaline reaction is the best condition for photographic operations. The phosphorus which it contains is a most important element of success, while the sulphur does not appear to have any prejudicial effect on the subsequent process with the aceto-nitrate of silver.

"The earnest inquirer is referred to Lehmann's 'Physiological Chemistry,' published by the Cavendish Society; article *Albumen*, vol. i. p. 330; and *Fluids of Eggs*, vol. ii. p. 353; a work that ought to be carefully studied by every chemist who desires to obtain accurate and recent information on this important subject.

"For the photographer's purpose the albumen of the hen's egg is the easiest of access. The eggs must be fresh, not more than five days old. They ought to be kept in a cool place. Those from the country are better than town-laid eggs, and I advise, where practicable, that the hens should have carbonate and phosphate of lime strewn about for them to peck at. This enriches the albumen and renders it more limpid. Each egg must be broken separately into a shallow cup, and the yolk retained in the shell as well as the germ; then poured into a measure until the required quantity of limpid albumen is obtained.

"To M. Niepce de St. Victor we are indebted for the first application of albumen to photography. In the latter part of 1848 I first saw an imperfect impression of some chimney-pots, at Chs. Chevallier's, optician, Paris; he could not, or would not, tell me how it was done. It was sufficient to know that the thing was possible, to make me attempt it again.

"I shall in this paper confine myself to the negative process, merely remarking, that the only difference between the negative and the positive process consists in substituting the chloride of sodium for the bromide of potassium.

"*Cleaning the Glass.*—New patent plate-glass is the best. Get into the habit of placing the face-side towards the wall, and into the boxes with the face towards the left hand. Solution:—Alcohol, 30 grammes (450 grains); strong liquid ammonia 10 grammes (150 grains); water, 40 grammes (600 grains); tripoli, 30 grammes (450 grains). Shake up to mix.

"Tie up three pieces of clean cotton wool in round balls, each about the size of a small hen's-egg; then fix the glass firmly in a wooden screw-vice perfectly flat; with a piece of cotton and the above solution rub hard and evenly the surface of the glass, in a similar manner as for Daguerreotype plates; then more gently; rear it up to dry. Take another glass, which rub in the same manner, and so on for twelve dozen. Change the ends to dry the upper edge of the glass. When dry, wipe the edges, as also the back, slightly with another ball of cotton, without touching the surface to free it from dust. Rub off the surface with a clean ball of cotton, firmly at first, then softly and evenly; then, with a clean hog's-hair brush, dust the back and edges, and, put the glass into a dry clean box, face towards the left hand. My boxes hold fifty plates each. The plate must be albuminized the same day; if left, it will be necessary to clean them again. This plan of cleaning is both for negative and positive glass.

"*Spreading on the Plate.*—For twelve dozen plates the albumen should be prepared as follows:—Take 450 fluid grammes (about 12 ounces) of albumen; 7½ fluid ditto (112 grains) saturated solution iodide of potassium; 1½ ditto (23 grains) bromide of potassium; 1 drop of solution of caustic potash; 1 gramme (15 grains) of water.

"The iodide and bromide of potassium ought to be each a saturated solution in distilled water, at a temperature of 60°, and weighed in a cup carefully balanced. The utmost care is necessary to observe these proportions; if too much of the salts be used, they crystallise in the albumen and make spots; the drop of caustic potash renders the albumen more limpid; pour the above ingredients into a wide-mouthed and rather large bottle (say half-gallon), shake up until the bottle is completely filled with white foam. This will take ten minutes. Let it stand six hours in a cool place; then pour off the clear albumen into a tall glass measure that does not taper towards the bottom, but rather, like a decanting vessel, broader at the bottom, to allow any particles of germ to fall down and not stick to the sides. The solution should be poured into this vessel one hour before it is required.

"It is now necessary to avoid most carefully the formation of air-bubbles, which, in the act of spreading, deteriorate the impression by making streaks; these are caused by the partial drying and decomposition of the chemicals in the albumen.

"I have found the following the most effectual way to avoid these faults. I have a glass funnel with a long beak that just reaches to the bottom of my glass pint-measure, upon which funnel I place a flat plate of glass turned up at the edges, with a hole in the centre; the whole is lined with moistened muslin, so that when the albumen falls on to the glass dish, in the act of pouring, it glides gently down into the measure placed under. The funnel is supported by a convenient wooden stand, termed in the laboratory a filter support.

"I place a wet sponge—also covered with clean muslin—on a table near at hand, between the above arrangement and the drying-box.

"Let us suppose then that the dish is ready, the drying-box placed perfectly level, the plates of glass all clean, a soft flat camel's-hair brush well dried and at hand. I take a glass, balanced on the tips of the fingers of the left hand, brush off the dust, and from the measure of albumen pour on to the surface sufficient to well cover the plate; keeping it as level as possible, then suddenly turn it down on its edge, to allow the excess of albumen to run into the glass dish; wiping it carefully for eight seconds on the edge of the muslin, then again eight seconds on the sponge cushion, and placing it in the drying-box. A few trials will give the exact moment necessary to deposit sufficient albumen on the surface; if too much remains, the plate will be streaked and uneven; if too little, the proof will be thin and weak. Continue spreading till the drying-box is full. The French albumen drying-boxes are the only ones I can use, and I therefore recommend them. Each board should be tried with a spirit-level. The plates will be perfectly dry in three days; put them into boxes in a dry place, where they will keep for any length of time, though it is best not to prepare more than one month's supply beforehand; four dozen plates can be coated in an hour.

"*To Iodize the Plates.*—As before stated, an alkaline reaction is the best condition for spreading the albumen, as it renders it more limpid; but this alkalinity is detrimental to the silvering process (an acid reaction now being of equal importance). The plates have, therefore, to be passed over the vapour of iodine, just like a Daguerreotype plate, to completely saturate the alkaline reaction; this will take from two to four minutes, according to the temperature; the albumen surface ought to have a yellow tinge, by the vapour of iodine; this operation ought to be done a few hours before silvering.

"*Silvering the Plates.*—The process of silvering is performed as follows:—Take 1,500 grammes (50 ounces) of water, 150 grammes (about 4 ounces) of nitrate of silver, and 150 grammes (about 4 ounces) of glacial acetic acid. Filter; use gutta-percha baths as for collodion. I use two baths and a bath of distilled water, and so arrange the dipping that each plate remains in the bath one minute and a-half. I then put each plate in succession into the bath of distilled water, washing the back with common, and the face with distilled, water; rearing up to dry in a place free from dust.

"This operation is quite mechanical, and much easier to do than to describe. At first the operator is afraid to run sufficient water on the plate to wash it; but he need have no fear, as the iodo-bromide of silver is precipitated into the substance of the albumen and cannot be washed out. The washing serves to make the operation more certain.

"Renew the silver bath as follows:—For every 100 plates add thirty grammes (450 grains) of nitrate of silver, twenty grammes (300 grains) of glacial acetic acid, and water to make up the original quantity.

"*To Prepare the Plates.*—In preparing the plates for the camera, pass them over the vapour of iodine half a minute previous to placing them in the camera slide; expose in the camera from thirty seconds to ten minutes, according to the intensity of the light, the colour of the object, and the aperture of the camera; if required to be very quick, the plate should be plunged into a dilute bath of gallic acid—one of acid to ten of water. This last suggestion is made for plates to be used immediately.

"*To Develop the Image.*—In order to develop the latent image, use (B) a saturated solution of gallic acid. (C) 400 grammes (13 ounces) of water, thirty grammes (450 grains) of nitrate of silver, and eighty grammes (3 ounces) of acetic acid. (D), a pint bottle filled with three parts of gallic acid solution and one part water. Pour into a dish, kept expressly for this purpose, about half an inch of liquid in depth, drop into it eight drops of solution (C), shake it up; then run distilled water on to the plate just taken from the camera, and plunge it into the gallic acid (D) as above prepared; shake it about, fill the dish with plates, and continue to shake up, adding every hour eight to twenty drops of solution (C), until the image is fully developed. The operation may be continued with safety for three days if necessary, though it is best to complete the developing in twelve to sixteen hours. Wash well with water, rear it up to dry.

"Another and quicker method of developing is with the pyrogallic acid:—300 grammes (9 ounces) of water, one gramme (15 grains) of pyrogallic acid, five grammes (75 grains) of glacial acetic acid, and one gramme (15 grains) of formic acid. The plates will develop in half an hour in this solution, and in warm weather in less time; but I find the half-tones are not so well preserved as in the slow process.

"*Fixing.*—The fixing is performed as follows:—100 water, ten hyposulphite of soda. Continue the fixing till all the yellow iodide disappears; wash well—dry—and the plate is finished.

"The hyposulphite solution should be kept entirely apart from the albuminizing; in fact, it should not be in the same room.

"The positive plates are prepared in the same way, only substituting chloride of sodium for the bromide of potassium. The exposure by superposition ought to be in north light ten seconds to one minute and a-half, according to the intensity of the negative proof.

"I find collodion negatives print much quicker than albumen negatives; collodion is more transparent.

"I recommend the glass to be an inch larger each way than the desired view, to allow for marginal error.

"Also always, if possible, to use new glass, as I find that which has been already used is uncertain.

"I have taken one hundred plates, prepared as above directed, without having a single failure. In fact, each plate receives precisely the same treatment, and if the directions are strictly followed, failure is almost impossible.

"Should the operator be compelled to use his glasses over again, I recommend that the albumen surface be washed off with caustic potash, and a scratch made with a diamond on the albumen side, so as to use the other; then wash the glass plates with common water, then with nitric acid and cotton, then much water again, then warm water, and rear up to dry, after which, clean as for new glass.

"The solutions must be carefully corked up to avoid evaporation, the gallic acid bottles kept full, the room free from dust, and dark thick yellow curtains to exclude the actinic rays. The plates will keep excited for fourteen days, and may be developed six days after the view is taken, which, to many photographers, may be an advantage.

"Never allow a sulphur match to be lighted in the albumen room; avoid vulcanised india-rubber rings, the sulphur from which produces spots; wash the developing dishes every time they are used with nitric acid, and much water afterwards; wash the silver baths with distilled water, and then turn them upside down to avoid dust.

"I recommend French weights and measures: the gramme weight is 15·43 grains (nearly 15½), the fluid ounce is equal to 31 grammes."

Mr. Negretti's Albumen Process.—After some directions for selecting and cleaning the plate of glass, the writer proceeds as follows:—

"*The Albumen.*—The manner of making albumen is very simple. You provide a rather large basin—I would recommend a Berlin evaporating basin with a small lip; you then procure a wooden fork, which is to be bought at most fancy bazaars; but a silver one is as good. Now get some good large eggs, all of a size, if possible. We reckon a large egg to contain thirty grammes (very nearly an ounce) of albumen, and we very seldom make more than 300 grammes (or 10 ounces) of albumen at a time, for which purpose we employ ten eggs. We always prefer having, or making, it fresh. Break the eggs one by one on the edge of a cup, and separate the yolk from the albumen, using the shells themselves for the purpose. Care must be taken not to leave any of the germ in the albumen. Throw the produce of one egg into the basin, and then break all the others one by one on the edge of the cup, after each operation emptying it into the basin. Into the albumen put one per cent. of iodide of ammonium or potassium, and twenty per cent. of distilled water. I mostly mix the iodide and distilled water in a glass vessel graduated into grammes, previous to putting it into the albumen; but either plan will answer. Now with the fork you beat the albumen into a thick froth. This will take about a quarter of an hour. The froth must be so thick and hard, that a piece may be pulled up bodily with a fork stuck into it. We prefer using iodide of ammonium, for we have found that iodide of potassium has sometimes caused the blacks in our negatives to become full of minute holes. The albumen having been beaten a sufficient time, cover the basin with a clean sheet of paper and put it away somewhere out of the dust. Many persons decant the albumen off from the basin, but I prefer using it out of the basin itself, because the albumen, after it has subsided, leaves a thick crust on the top, and in order to pour it on the plate it has to force itself through this crust, consequently it filters itself at the same time.

"*The Drying Box.*—The box for drying the plates must be well made, with a number of grooves running parallel to each other, and the exact width of your glasses. In each alternate groove there is a board, made so as not to twist easily by being heated, and sliding freely in the grooves; the box must also have an arrangement for rendering it perfectly level. This box, previous to its being used, must be well dusted inside; the boards also must be well cleaned, and each well dried and heated—if in summer, in the sun, or in winter before a fire. If your box and boards are not thoroughly desiccated and rendered absorbent, your plates will not dry easily. Having now your box, glasses, and albumen ready, carry all these things *at once* into your albuminizing room. I say, at once, for if you go in and out of the room you will create such a dust that it will not be possible for you to cover the plates nicely and cleanly.

"The room should be prepared some two or three hours before you want to use it; and it should be well watered and swept, and if there are any shelves, or other places likely to harbour dust, they should be well wiped with a wet sponge; for it must be borne in mind that dust is your great enemy in the albumen process.

"*Plate-holder.*—To albuminize the glasses you must provide a plate-holder. The one I recommend is a round stick, about half an inch in diameter, and eight or nine inches long, tapering at one end; it has at the other end a small cup, about one inch or more in diameter. Round the edge of the cup, which is about a quarter of an inch thick, is melted some gutta-percha. This makes the best holder I have yet tried.

"*Spreading the Albumen.*—Now get a sheet of clean paper, and spread it on a table before you; also light a spirit-lamp, and have a small glass rod and a fine camel's-hair pencil on the same table, taking one of the glasses, which should be marked with a small adhesive label to indicate the side you do not intend to albuminize. Place this glass with its best side flat on the sheet of paper; then take the plate-holder and warm the gutta-percha gently over the spirit-lamp. Upon placing the warm part on the back of the glass, you will find that in a few seconds you will be enabled to lift the glass, and handle it, or turn it as you wish. The albumen is now poured upon the glass; should it not spread evenly, the little glass rod will enable you to guide the albumen wherever you like. The albumen is allowed to drain off first at one corner and then at the other. Turning it over, allow it to descend to the bottom, and that will be the second time the albumen has gone over the glass. It is then turned back again, and allowed to go half way. At this stage a rotatory motion is imparted to the glass by means of the holder, which is continued for about seven or eight seconds; then the holder is taken hold of close under the glass and the plate forced off the gutta-percha. The glass is now placed in one of the grooves of the drying-box, which is shut close until you are ready with the next plate. Of course, the operation must not take so long a time to perform as I have taken to describe it. The small camel's-hair pencil serves to pick off any dust that might accidentally fall on the plate during the time you are spreading the albumen; draw the pencil between your lips and use the point thus made for that purpose. After remaining in the drying-box a few hours, your plates will be hard enough for the next operation, which is—

"*Making the Plates Sensitive.*—The bath we use for this purpose is a horizontal one; it is a flat dish made with a piece of plate-glass, having tight wooden sides like a shallow box, the plate-glass forming a nice flat bottom. The dish should be about one-third longer than your plates. The solution is composed of distilled water, nitrate of silver, and glacial acetic acid, in the proportion of ten of nitrate of silver and ten of acetic acid to every hundred of water. The quantity required is, of course, according to the size of your plate. This solution is to be poured, say a quarter of an inch deep, into the dish, one end of which is raised as much as you can without spilling the solution; the albuminized plate is then placed face upwards in the upper or empty part of the dish; then, by a little dexterous movement, you suddenly, by bringing the dish level, cause the solution to flow quickly and evenly over the plate, which is left in the bath about forty seconds. It is as well to raise the plate up several times, and otherwise agitate the bath; for this purpose you use a small piece of silver wire flattened and bent at right angles at one end. The flat part is inserted between the glass and the dish, and the plate lifted by it. You must be very particular in rendering your plate sensitive, for if you do not get your solution quickly and evenly over the plate, you will have a sharp and clear outline wherever you have stopped, precisely as if the negative had been cracked. The plate is now taken out of the bath, and present a nice light-blue tint. It is immediately well washed with distilled or water, and must be washed back and front, especial care being taken that not an the aceto-nitrate is left on the plate, or your picture will at that spot turn black. water must flow evenly over the plate, and no greasy streaks be perceptible; until takes place, your plate is not washed enough. The plate is now placed in a large having some blotting-paper at the bottom to facilitate draining, and is then ready use.

"*Exposure in the Camera.*—If your object is near, your plate will be more sensit if used wet at once; but for keeping, it is best to let the water dry off previously to plate being placed in the slide.

"The time of exposure depends of course on the light, the object you have to ta and on the focal length of your lens; but in summer we have taken a good negati with ten minutes' exposure. In France or in Italy good albumen negatives are tak in three or four minutes. A little practice, however, will soon determine the prop time of exposure required.

"*Developing the Image.*—I take a saturated solution of gallic acid, and a solution nitrate of silver of two per cent., viz., two grammes (31 grains) of nitrate to one hundre of distilled water. I get a nice soft brush or pencil, with hair about three-quarters or o inch long. After placing the plate on a level developing stand, I warm my gallic aci to a temperature of about 80° Fah., and pour on the plate enough to cover it, using the brush to spread it over the plate rapidly (you need not have the least fear in using the brush, for it will almost require a knife to injure the albumen). After allowing the gallic acid to remain about one or two minutes, I pour part of it off, and add to it some of the nitrate solution, the brush being instantly at work in mixing the two solutions together, forming a gallo-nitrate. The mixing on the plate must be instantaneous; in fact, I usually pour the nitrate on the brush, which I rest on the plate. My picture begins now to appear. Should I find, after a little time, that the image does not show itself, which would be the case if the plate were under-exposed, I throw off this solution, and begin again with the warm gallic acid, adding nitrate solution, repeating the operation again and again, until my picture is fully developed. By these means, and by repeatedly re-changing the bath, you are enabled to coax into a very good picture a plate that you have not been enabled to expose sufficiently, either by reason of some one having accidentally moved your camera, or by your being obliged to leave the spot, and which would thus, in any other process, have been a failure.

"The same rule holds good, if, whilst developing, you find you have not sufficient time to finish your picture. You have merely to well wash off the solutions, put the plate away in the dark, and you can resume the development at your leisure, a week after if you wish.

"We do not always succeed in developing our pictures so quickly, but by attention and care negatives should never take more than from half-an-hour to three-quarters; it is not imperative to warm the gallic acid, but by so doing you greatly accelerate the development. The picture is now washed and ready for

"*Fixing.*—This is done with hyposulphite of soda, just in the same way as in fixing a collodion negative; but no cyanide must be used, for that will take off your albumen.

"Positive pictures on glass are generally printed on plates extra thinly albuminized for the purpose, which is effected simply by rotating the plate more rapidly and for a longer time. These also must be developed as quickly as possible; but do not be pted to use stronger nitrate solution for that purpose, or you will spoil your pictures. e great fault of the albumen positives I have seen produced in England is, that it evidently taken such a long time to develop them that they have looked opaque, e bad Daguerreotypes, having a metallic deposit on them which is disgreeable to the , and which renders them anything but transparent."

There is a modification of the albumen process much used in America, and I believe h good results—it is called "Whipple's Albumen Process," having been introduced Mr. Whipple of Boston, a gentleman well known in the photographic world.

Mix in the usual manner:—Albumen, eight ounces; honey, seven ounces; iodide potassium, three drachms; bromide of ditto, twenty grains; chloride of soda, nine ins.

For foliage, increase the bromide of potassium up to fifty grains.

This mixture is poured on the glass plate in the same manner as collodion, and then ed over a spirit-lamp. The plate is then immersed for ten to twenty seconds only the following bath:—

Nitrate of silver, one and a-half ounces; water, sixteen ounces; acetic acid, ur ounces.

After the dipping, the plate must be well washed, and if all the free silver is washed f, the plates will keep for four weeks. Develop with a saturated solution of gallic id and nitrate of silver, and fix in the usual manner with hyposulphite of soda.

Collodion Process.—Collodion as a photographic medium is, without doubt, far efore any other. The beauty of the details obtained in good pictures taken by this rocess, the exceeding sensibility of the medium itself, and the comparative ease of its anipulation, place it at the head of *all* photographic agents. I shall, therefore, go to this branch of the art as fully as possible, preferring rather to say too much than o little.

Mr. Archer, who was the first, in conjunction with Mr. Fry, to introduce this impor- nt addition to the art, deserves our utmost thanks for enabling us to obtain effects so tterly impossible to be obtained by any other means. Some idea of the value of the iscovery may be formed from the fact, that instantaneous pictures have been taking by r. Fenton, of clouds, waves, shipping, animals, figures, &c., by a single lens. On one ccasion, where a man was running, the leg that was on the ground when the lens was ncovered was perfectly defined, while the other left three or four impressions in its ansit during the moment of exposure.

Choice of Glass.—This may be classed under five heads:—Cleaning the plates, coating with collodio-iodide of silver, exposure in the camera, developing the image, fixing the image; but first a few words on the choice of the glass. Here we can follow no more faithful guide than Mr. Hardwich:—

"Much care should be taken in the selection of glass intended to be used for photographic purposes. The ordinary window-glass is often inferior, having scratches upon the surface, each of which causes an irregular action of the developing fluid. Also the squares are seldom perfectly flat, so that they do not touch the slide at every point, and hence a part of the image is out of focus. A more serious inconvenience, arising from want of flatness, is, that the plates are apt to be broken in compression during the printing process.

"The patent plate answers perhaps better than any other description of glass, but if that cannot be procured the 'flatted crown' may be substituted.

"*Cleaning the Plates.*—Before proceeding to wash the glasses, each square should be roughened on the edges by means of a file or a sheet of emery-paper. If this precaution be omitted, not only are the fingers liable to injury, but the collodion film is apt to contract and separate from the sides.

"In the process of cleaning the glasses, it is not sufficient—as a general rule—to wash them simply with water; other liquids are required to remove grease, if any is present. For this purpose, perhaps, caustic potash, sold in druggists' shops under the name of 'liquor potassæ,' is as good as any; or, if that is not at hand, a warm solution of common 'washing soda,' which is carbonate of soda.

"Liquor potassæ, being a very caustic and alkaline liquid, requires care in the handling; it softens the skin, and dissolves it away even more so than acids. A safe plan of proceeding is to dilute the potash with about four parts of water, and to apply it to the glass by means of a cylindrical roll of flannel; after wetting both sides of the glass thoroughly, allow it to stand for a time until several have been treated in the same way; afterwards wash well with water and rub dry in a cloth.

"The cloths used for cleaning glasses should be kept expressly for that purpose; they are best made of a material sold as 'fine diaper,' and very free from flocculi and loosely adhering fibres. They are not to be washed in soap and water, but always in pure water or in water containing a little carbonate of soda.

"After wiping the glass carefully, complete the process by polishing with an old silk handkerchief, avoiding contact with the skin of the hand. Some object to silk, as tending to render the glass electrical, and so to attract particles of dust, but in practice no inconvenience will be experienced from this source. Before deciding that the glass is perfectly clean, never omit to hold it in an angular position and to breathe upon it.

"The use of an alkaline solution is usually sufficient to clean the glass, but occasionally we meet with plates dotted on the surface with small white specks, which are not removed by the potash. These specks consist frequently of hard particles of carbonate of lime; and when that is the case they dissolve very readily in dilute sulphuric acid, in about four parts of water, applied by means of a roll of flannel. Nitric acid, also diluted in four parts water, also answers the same purpose; but it destroys any dress it comes in contact with, unless it is at once treated with liquor ammonia or some other alkali."

Some operators employ cyanide of potassium, and others ammonia, in cleaning the plates. A mixture of Tripoli powder and spirits of wine is preferred by those who fear injuring the skin by the use of alkalies and acids.

When positives are to be taken, it is advisable to use additional care in preparing the glass, and especially so with the pale, transparent film and neutral nitrate bath.

After a glass has once been coated with collodion, it is not necessary in cleaning a second time to use anything but pure water; but if the film has been allowed to harden and dry upon the glass, possibly the dilute oil of vitriol, or cyanide of potassium, may be required to remove stains.

If, under similar circumstances, a greasiness is perceived, which prevents the plate from being wetted evenly by a stream of water poured upon it, it may be removed by a second application of alkaline liquid.

The Collodion.—Of the collodion itself, no better instructor can be followed than Mr. Edward Ash Hadow, whose address to the Photographic Society we cannot do better than quote:—

"Having," says that gentleman, "experienced some difficulty in producing at all times a collodion of uniform sensitiveness, tenacity, and fluidity, although making use of the same materials for its preparation, and this as I find being the complaint of many others, it has been my study lately to determine the variations in quality to which the ingredients are liable, and the effects of those variations on the sensitive film; and likewise to ascertain whether the qualities depend on the materials in ordinary use, or on some substances accidentally or intentionally added. Researches on the preparation of collodion may appear superfluous, now that it is supplied of the best quality by so many makers; but as some persons of an independent turn of mind still prefer manufacturing their own, I venture to bring forward the subject with the hope of assisting them. In this beautiful process success depends so much on the quality of the collodion, that, when in possession of a good specimen, it becomes one of the easiest and most simple, and ought to be the most certain of all the processes; for no material, such as paper, of uncertain composition is introduced, we have nothing to fear from plaster of Paris, alumina, or specks of iron or copper, which continually endanger or modify the calotype process; each ingredient can and ought to be obtained in a state of perfect purity, and with this knowledge the degree of success depends upon the skill of the operator himself.

" Of all the substances used in this process, the gun-cotton is usually the only one actually prepared by the operator himself; in this case he cannot fail to have observed the great variations in solubility, and, when dissolved, in the transparency and tenacity of the films, to which it is liable; the various processes also that are given appear at first sight unaccountably different, some directing ten minutes', others a few seconds' immersion. I have examined into the cause of these variations, with a view to obtain certainty, and have also endeavoured to discover how far they affect the sensitiveness of the prepared surface. If we take a mixture of the strongest nitric and sulphuric acids, and immerse as much cotton as can be wetted, after some minutes squeeze out the acid as far as possible, then immerse a second portion of cotton, and again express the acids for a third portion of cotton, and so on until the liquid is exhausted, we shall find, on comparing the cottons thus treated, after washing and drying them, that there is a gradual alteration in their properties, the first being highly and perfectly explosive, and each succeeding portion less so, until the portion last immersed will be found hardly explosive at all, leaving distinct traces of charcoal or soot when burned.

"This may not appear surprising at first sight, as it may be imagined that the latter portions are only a mixture of gun-cotton and common cotton; this, however, is not the case, for if each quantity be immersed sufficiently long, it will not contain a fibre of common cotton, and may yet become charred on burning like unaltered cotton. The most remarkable difference, however, is discovered on treating them with ether containing a little alcohol, when, contrary to what might have been anticipated, the first or strongest gun-cotton remains quite untouched, while the latter portions dissolve with the utmost ease, without leaving a trace behind; this alone is a sufficient proof that no unaltered cotton remains. This difference in properties is owing to the gradual weakening of the acid mixture, in consequence of the nitric acid being removed by the cotton, with which it becomes intimately combined, at the same time that the latter gives out a proportionate quantity of water.

" In consequence of these experiments, a great many mixtures of these acids were prepared of various strengths, each being accurately known, both to determine whether there were more than one kind of soluble gun-cotton; and, if there were, to ascertain exactly the mixture required to produce that most suitable to photographic purposes. By this means, and by, what I believe has not been pointed out, varying the temperature, at least five varieties were obtained:—First, gun-cotton properly so called, as before stated, quite insoluble in any mixture of alcohol and sulphuric ether. Secondly, an explosive cotton, likewise insoluble, but differing chemically from the first, obtained by a mixture of certain strength when used cold. If warm, however, either from the heat produced spontaneously on mixing the two acids, or by raising the temperature artificially to about 130°, the cotton then immersed becomes perfectly soluble, producing a third variety; if, however, it be thoroughly dried it becomes in a great measure insoluble. The fourth is obtained by the use of weaker acids used cold, and the fifth when the mixture has been warmed to 130° previous to the immersion of the cotton; in either of the last two cases the product is perfectly soluble, but there is a remarkable difference between their properties, for on dissolving six grains of each in one ounce of ether, the cotton treated with warm acids gives a perfectly fluid solution (which is likewise the case with the third variety produced by acids somewhat stronger), while that obtained by the use of cold acids makes a mixture as thick as castor-oil.

"Having obtained these more strongly-marked varieties, as well as intermediate kinds with all gradations of solubility, it was necessary, before I could select any particular formula for preparing the cotton, to compare their photographic properties, with especial reference to sensitiveness, opacity of the reduced silver in negatives, and its colour in positives. A certain weight of each being dissolved in a portion of the same mixture of alcohol and ether previously iodized, the comparison was made, by taking the same objects with each collodion in succession, and likewise by pouring two samples on the same plate of glass, and thus exposing them in the camera together side by side. This last proved to be much the most satisfactory plan, and was repeated many times for each sample, taking care to reverse the order in which they were poured on, that there might be no mistake arising from the difference of time elapsing between the pouring on of the collodion and its immersion in the sensitive bath. By these experiments I had confidently hoped to have solved the question as to the cause of difference in sensitiveness and other photographic properties of collodion; but in this I was disappointed, for, after repeated experiments, I believe I may safely affirm that they are precisely similar as regards their photographic properties. The same, I believe, may be said of Swedish paper collodion, judging from a few comparative experiments I have made, and indeed it is difficult to discover what is the superiority of this material over clean cotton-wool. The ease of manipulation, which some allege, is a matter of taste; but I should decidedly prefer the open texture of cotton to that of a substance like filtering paper, composed of a mass of compacted fibres, the innermost of which are only reached when the acids have undergone a certain degree of weakening by the water abstracted from the outer fibres; and when we consider that from cotton alone we have the means of preparing all varieties of collodion, from the most powerfully contracting and transparent to the weakest and most opaque, and each if required with equal and perfect certainty, there appears to be choice enough without resorting to another material, differing only in being more rare and more difficult to procure. But although the photographic properties of these varieties of collodion-wool are so similar, other circumstances, such as fluidity, tenacity, and transparency, render its preparation of some importance, and indicate that the acid mixture should always be used warm; and it is chiefly in consequence of this very circumstance, that greater success attends the use of nitrate of potash and sulphuric acid than that of mixed acids; for the former when mixed produce the required temperature, and must be used while warm, since on cooling the mixture becomes solid, whereas acids when mixed do not usually produce so high a temperature, and being fluid can be used at any subsequent period. Another obstacle to their use is the great uncertainty of the strength of the nitric acid found in the shops, requiring a variation in the amount of sulphuric acid to be added, which would have to be determined by calculation or many troublesome trials. When a proper mixture is obtained, the time of immersion is of no importance, provided it be not too short, and the temperature be maintained at about 120° or 130°; ten minutes is generally sufficient (though ten hours would not render the cotton less soluble, as is sometimes asserted).

"In using the mixed acids, the limits are the nitric acid being too strong, in which case the product is insoluble, or too weak, when the cotton becomes immediately matted, or even dissolved if the mixture is warm. I have availed myself of these facts in order to produce collodion wool by the use of acids, without the trouble of calculating the proper mixture according to their strength. Five parts by measure of sulphuric acid, and four of nitric acid of specific gravity not lower than 1·4, are mixed in an earthenware or thin glass vessel capable of standing heat; small portions of water are added gradually (by half drachms at a time, supposing two ounces to have been mixed), testing after each addition by the immersion of a small portion of cotton; the addition of water is continued until a fresh piece of cotton is found to contract and dissolve on immersing; when this takes place, add half the quantity of sulphuric acid previously used, and (if the temperature does not exceed 130°, in which case it must be allowed to cool to that point) immerse as much cotton, well pulled out, as can be easily and perfectly soaked; it is to be left in for ten minutes, taking care the mixture does not become cold; it is then transferred to cold water and thoroughly washed. This is a matter of much importance, and should be performed at first by changing the water many times, until it ceases to taste acid, treating it then with boiling rain-water until the colour of blue litmus remains unchanged; the freedom from all trace of acid is insured by adding a little ammonia before the last washing. Cotton thus prepared should dissolve perfectly and instantaneously in ether containing a little alcohol, without leaving a fibre behind, and the film it produces be of the greatest strength and transparency, being what M. Gaudin terms 'rich in gun-cotton.' The mixture of nitrate of potash and sulphuric acid is defective chiefly from the want of fluidity, in consequence of which the cotton is less perfectly acted on; this may be remedied by increasing the amount of sulphuric acid, at the same time adding a little water. A mixture of five parts of dried nitre, with ten of sulphuric acid, by weight, together with one of water, produces a much better collodion wool than the ordinary mixture of one of nitre with one and a-half of sulphuric acid. The nitre is dried before weighing, in order that its amount, as well as that of the water contained in the mixture, may be definite in quantity; it is then finely powdered, mixed with the water, and the sulphuric acid added; the cotton is immersed while the mixture is hot, and afterwards washed with greater care even than is required when pure acids are used, on account of the difficulty of getting rid of all the bisulphate of potash that adheres to the fibres, which both acts as an acid and likewise causes the collodion to appear opalescent when held up to the light—whereas the solution should be perfectly transparent.

"Having obtained good collodion wool, the next point of inquiry was with regard to the solvent: to ascertain whether the addition of alcohol beyond what is absolutely necessary to cause the solution of the gun-cotton in ether, was beneficial or otherwise.

For this purpose ether and alcohol were prepared perfectly pure, and mixtures were made of one of alcohol to seven of ether, two to six, three to five, four to four, and five to three. In one ounce of each were dissolved six grains of gun-cotton and four grains of iodide of ammonium (iodide of potassium could not be employed, since it requires a certain amount, both of water and alcohol, to keep it in solution); they were then compared, using a thirty-five grain solution of nitrate of silver, both by pouring on separate glasses, and likewise by covering two halves of a plate with two samples, as in examining the gun-cottons, thus placing them under the same circumstances during the same time; in this way the effect of adding alcohol was very clearly perceived, since the differences between the collodions was much greater than could have been anticipated. The first mixture containing only one-eighth of alcohol was quite unfit for photographic purposes, it being almost impossible, even with the most rapid immersion, to obtain a film of uniform sensitiveness and opacity throughout, the surface generally exhibiting nearly transparent bands, having an iridescent appearance by reflected light. The second mixture, with one-fourth of alcohol, is liable to great uncertainty, for if there be any delay in pouring off the collodion, the same appearances are seen as in the first, and, like it, the surface is very insensitive to light, while, if the plate be rapidly plunged in the bath, the collodion film becomes much more opaque than before, and is then very sensitive. The third proportion of three of alcohol to five of ether, is decidedly the best, giving without the least difficulty a film beautifully uniform and highly sensitive, at the same time perfectly tough and easily removable from the glass if required. A further addition of alcohol, as in the last two collodions, was not attended with any corresponding advantage or increase of sensitiveness; on the contrary, the large proportion of alcohol rendered them less fluid, though with a smaller quantity of gun-cotton they would produce very good collodions, capable of giving firm films. The cause of the weakness of the film observed on adding much of the ordinary alcohol is the large amount of water it usually contains.

"This surprising improvement, caused by the addition of a certain quantity of alcohol, is referable to causes partly chemical, partly mechanical, for on examining the films it will be found in the first, and occasionally in the second collodion, that the iodide of silver is formed on the surface, and can be removed entirely by friction without destroying the transparent collodion film below, while in those collodions that contain more than one-fourth of alcohol, the iodide of silver is wholly in the substance, and in this state possesses the utmost sensitiveness. This difference of condition is owing to the very sparing solubility of ether in water, which in the first case prevents the entrance of the nitrate of silver into the film, consequently the iodide and silver solutions meet on the surface; but on the addition of alcohol, its solubility enables the two to interchange places, and thus the iodide of silver is precipitated throughout the substance in a state of the utmost division.

"This difference is clearly seen under the microscope, the precipitate being clotted in the one case, while in the other the particles are hardly discoverable from their fineness. The presence of a little water considerably modifies these results, since it in some degree supplies the place of alcohol, and is so far useful; but in other respects it is injurious, for accumulating in quantity, if the collodion is often used, it makes the film weak and gelatinous, and what is worse, full of minute cracks on drying, which is never the case when pure ether and alcohol are used. Since the ether of the shops almost always contains alcohol, and frequently water, it is important to ascertain their amount before employing it for the preparation of collodion. The quantity of alcohol may be easily ascertained by agitating the ether in a graduated measure glass (a minim glass does very well) with half its bulk of a saturated solution of chloride of calcium. This should be poured in first, its height noticed, and the ether poured on its surface, the thumb then placed on the top, and the two agitated together; when separated, the increase of bulk acquired by the chloride of calcium indicates the quantity of alcohol present, and for this, allowance should be made in the addition of alcohol to the collodion afterwards. Water is readily detected, either in ether or alcohol, by allowing a drop to fall into spirit of turpentine, with which they ought to mix without turbidity; this is immediately produced if they contain water. For detecting water in alcohol, benzole is a more delicate reagent than spirit of turpentine (Chemist, xxix. 208). It is also necessary that ether should be free from a remarkable property it acquires by long keeping, of decomposing iodides and setting free iodine, which thus gives the collodion a brown colour. The same property may be developed in any ether, as Schönbein discovered, by introducing a red-hot wire into the vapour in the upper portion of a bottle containing a little ether and water; if it be then shaken up and a solution of an iodide poured in, the whole rapidly becomes brown. This reaction is very remarkable and difficult to explain, for even a mixture of ether and nitric acid fails to produce a colour immediately. Ether thus affected can only be deprived of this property by rectification with caustic potash.

"*Iodised Collodion.*—I have now a few remarks to offer on the modes of iodising or rendering the film capable of becoming sensitive, by the addition of some soluble iodide. Those that have been recommended are chiefly the iodides of potassium, ammonium, cadmium, and zinc: of these the last three have the great advantage of being readily soluble in any collodion, and may therefore be added at once to the solution of gun-cotton; but iodide of potassium requires a little water, and even then, if added to collodion without having been previously dissolved in some of the alcohol, will be found to dissolve but very slowly.

"In preparing collodion with this salt, four grains were dissolved in three drachms of strong alcohol, and ether was added to make up the ounce. I found that the first two and a-half drachms of ether began to precipitate the iodide, and after addition of the five drachms required, a dense deposit had formed, which was not re-dissolved until twelve drops of water had been added. This I merely mention to show that there must be a little water in the mixture, although in using ordinary ether and alcohol this might not be perceived. Before comparing collodion prepared with different iodides, it appeared probable that those of potassium and ammonium would produce greater sensitiveness than those of zinc and cadmium; for this reason, that the nitrates of ammonia and potash, which are produced together with iodide of silver, on immersing films prepared with the first two iodides in the nitrate bath, are perfectly neutral, while the nitrates of zinc and cadmium, which result when collodions containing those metals are used, have a feebly acid reaction on litmus paper, and thus by their presence in the film might, like weak acids, retard the action of light. In actual experiment, however, I did not find this to be the case, for when carefully and similarly prepared with equivalent quantities of each iodide, and used while colourless, the collodions appear similar in sensitiveness, gradation of tints, and all other respects. In a few days, however, they begin to differ in consequence of partial decomposition and liberation of free iodine, which occurs more readily with the iodides of ammonium and zinc than with potassium, while the iodide of cadmium, if I may conclude from one sample I have by me, remains perfectly colourless for any period of time, retaining its original sensitiveness, the other varieties having lost theirs in proportion to the colour they have acquired. The iodide of cadmium, in addition to this valuable property of giving a stable collodion, is likewise extremely soluble, without being deliquescent, and being beautifully crystalline, is not liable to adulterations or impurities, and therefore well deserves to be generally tried.

"In order to preserve or, as it is stated, to improve the sensitiveness of collodion, some persons recommend the addition of a little ammonia. This, however, appears very unadvisable, since it necessitates the use of an acid bath; and although it may render the collodion less liable to change, it produces a contrary effect on the bath, since every plate immersed tends to neutralize a portion of acid, and at length rendering it neutral or even alkaline, brings about exactly the phenomena (fogging) described by Mr. Fenton.

"The cause of fogging (which is blackening of the whole negative on the addition of the developing solution) is owing to the bath becoming alkaline. This alkaline reaction is caused by oxide of silver in a state of solution in the bath.

"Oxide of silver is not soluble in water, nor in water containing nitrate of silver; but it is, in either case, abundantly dissolved if nitrate of ammonia be present, and the solution will be found to restore rapidly the colour of reddened litmus paper.

"The 'alkaline nitrate of silver bath,' therefore so called, is a solution containing, besides nitrate of silver, oxide of silver, dissolved in nitrate of ammonia.

"The nitrate of ammonia is produced by double decomposition when compounds of ammonium are used for 'iodizing' instead of those of potassium. Iodide of ammonium plus nitrate of silver equals iodide of silver plus nitrate of ammonia.

"The oxide of silver, which by its solution causes the alkalinity, is formed either by using collodion containing a little free ammonia in addition to the other ingredients, as sometimes recommended, or by attempting to neutralize an acid bath with potash or ammonia, and inadvertently adding an excess.

"So that if ammonia or salts of ammonia in any shape have been added to the collodion, or to the bath, it will be necessary from that time forward to examine more carefully than we otherwise should have done, that the faintly acid condition of the bath, so essential to the production of a good picture, is not destroyed.

"With ordinary collodion, however, even when quite colourless, the bath may always be used perfectly neutral, permitting the developing solution to be left on twice or three times as long as is necessary, without the slightest fogging, provided that the nitrate of silver is pure and the bath has not acquired fogging propensities by prolonged use. No pure alkaline iodide can ever render the bath alkaline; the only effect on immersing a plate covered with collodion is to remove a portion of silver and substitute an equivalent quantity of potassium, ammonium, &c., so that a portion of nitrate of silver is merely replaced by a portion of nitrate of potash or ammonia, which, being neutral, cannot in this respect affect the state of the bath. With the iodides of the metals, such as iron, zinc, cadmium, or arsenic, the bath, on the contrary, will soon become apparently acid from the presence of the nitrates of those metals which, as before stated, redden litmus.

"In all cases, excepting when free ammonia has been added to the collodion, the silver solution has a tendency to become acid rather than alkaline, both from the frequent presence of free iodine in the collodion, which sets free nitric acid in the bath, and also from the slow formation of acetic acid from the alcohol and ether washed out from the plates that have been immersed. The effect of free iodine in the collodion is not, however, chemically the same as that of nitric acid in the bath; for nitrate of silver is, like all other nitrates, a nitrate of the oxide of silver. When, therefore, free iodine acts on the silver solution, it liberates oxygen as well as nitric acid, the result being that an iodate as well as an iodide of silver is formed; the effect of the former should therefore be ascertained, in order to clearly understand the action of brown collodion. When a great deal of iodine has been set free by long keeping, making the collodion very dark-coloured and insensitive, I found that the addition of a little oil of cloves, in the proportion of four drops to each ounce, causes a surprising increase of sensitiveness; and some time ago I always used such a mixture for the production of positives on glass, from a belief that a better colour and more perfect gradation of tints were obtained in this way than by any other method.

"At this time my pictures were constantly liable to solarization (or darkening of those parts that ought to be whitish), when using the ordinary collodion and developing by pyrogallic and nitric acids; but lately, while seeking for difficulties in order to discover their causes, this tendency to solarization quite disappeared, although using the simplest materials; neither was I able to produce it by taking objects in the most unfavourable conditions of light and shade, nor by any addition to the collodion. Accidentally trying the effect of a minute quantity of nitrite of silver in the nitrate bath, I obtained it again in perfection, and was able at once to understand how it occurred formerly, for at that time I always made use of nitrate of silver that had been strongly fused, and in which a portion of nitrite had thus been formed, while latterly only the crystallized salt had been employed. The effect of oil of cloves and iodine in the collodion was to counteract that of the nitrite; but when pure crystallized nitrate is used, no such additions are required.

"It is remarkable, that although oil of cloves greatly increases the sensitiveness when brown collodion is used, no such effect is produced by its addition to colourless collodion with an acid bath, proving that free iodine in the former is not exactly similar to nitric acid in the latter. To compensate for the bad effects of the nitrite on the colour of positives, it has the important property of much increasing the sensitiveness and rapidity of the surface, allowing pictures to be taken instantaneously with far less light than is usually required; and it is thus particularly suited to negatives, in which the colour by reflected light is of no importance, while it adds to the opacity of the dark parts of the picture. Its effect on the colour of positives is chiefly seen when pyrogallic acid is used for developing, and becomes more marked as the picture dries, when the tint of the reduced silver becomes darker, and of a greenish colour in the most exposed parts, while with pure nitrate, as the moisture evaporates, it becomes lighter, and the details appear more distinctly represented in various shades of one colour. As this nitrite is formed when the nitrate is overheated, it generally exists in 'lunar caustic' to a greater or less extent; but as this substance, from a want of crystalline form, is easily and frequently adulterated, it is much better to add the nitrite to a solution of the crystallized nitrate in quantities less than half a grain to an ounce of a thirty-five grain solution, for too large an amount causes a fogging of the clear parts of the picture. It is easily obtained by fusing pretty strongly a mixture of equal parts of nitre and nitrate of silver; the fused mass being dissolved in a small quantity of boiling water, and left to cool; the nitrite of silver then crystallizes in the shape of long, slender needles, which may be removed, and pressed in blotting-paper to dry them; by re-crystallizing they are obtained quite pure.

"The strength of the solution of nitrate of silver ought to be proportional to the quantity of iodide in the collodion, at least so far that it cannot be diminished beyond a certain point (depending on the collodion used) without a great loss of sensitiveness, or, what is exactly similar, if we use a bath of a certain strength, the quantity of iodide cannot be increased to any amount, but must be limited by the proportion of nitrate of silver: with a thirty-five grain solution of the latter, four grains of iodide to the ounce of collodion answers very well; but if the quantity be increased to six grains, there is a great loss of sensitiveness and intensity, the effect being similar to that arising from an insufficient amount of alcohol in the collodion, in consequence of the iodide of silver being deposited superficially, or even falling off the surface into the silver bath. The mistake of over-iodizing the collodion is generally committed with the view to obtain greater opacity of the reduced silver, apparently from an idea that the iodide only is reduced, while in fact a large portion of the reduced silver is derived from the nitrate, so that a very little iodide in the film is sufficient to give intense negatives. For this purpose the collodion should be colourless, or nearly so, or at least, if coloured, it must not be owing to free iodine (which is ascertained by allowing a drop to evaporate on a piece of starch or a crumb of bread, and then moistening with water; a trace of iodine is detected by the black colour resulting); the bath should likewise be neutral, or nearly so, and the developing fluid should contain no more acetic or tartaric acid than is sufficient to prevent blackening of clear parts; after the pyrogallic solution has apparently done its utmost, the intensity may be further increased by pouring on a fresh portion, mixed with some of the silver solution, which immediately adds to the opacity of the negative, a fresh deposit taking place on the parts already reduced. By the use of the nitrate as before mentioned, still greater opacity may be obtained, together with the utmost rapidity; at the same time there is none of that violent contrast of light and shade which appears to result from the addition of iodide of iron, as an accelerating agent, to the collodion. I believe that salts of iron have not as yet been used for developing negatives, in consequence of the want of opacity in the reduced parts. I find, however, that the proto-acetate of iron obtained by mixture of solution of acetate of lead and sulphate of iron, is capable of producing intense negatives, resembling in all respects those obtained by pyrogallic acid, while it has the advantage in point of economy; but I have not as yet made a sufficient number of experiments to enable me to determine the strength of the solution best suited to the purpose; it need not be very great, somewhat less than eighteen grains to the ounce, for if it contain so much as this, it is liable to produce universal blackening when first prepared; but in a few days, when a portion of peracetate has formed, it answers very well. My object in endeavouring to find a substitute for pyrogallic among the iron compounds, is not to add to the number of developing fluids and the perplexity of a beginner. Where pyrogallic acid can be obtained pure, and is found to answer perfectly, in that case it is preferable to anything else; but as this may not always be, it is useful sometimes to know of a substitute that can be prepared wherever green vitriol and sugar of lead can be found, for these substances, even when impure, are very easily purified by re-crystallizing from a solution in boiling water; which is not the case with pyrogallic acid, to which noxious ingredients might easily be added, accidentally or intentionally, from which it would puzzle a chemist to free it.

"By knowing the quantity of iodide contained in a collodion, it is easy to ascertain the amount of silver that the bath loses for each ounce, and thus to know exactly how much nitrate should be added to maintain the same strength; thus, with a collodion containing four grains of iodide of ammonium to the ounce, each ounce expended removes four seven-tenths grains of nitrate of silver, but with four grains of iodide of potassium the quantity of nitrate consumed is only four one-tenth grains. In the first case nitrate of ammonia, in the second nitrate of potash, accumulates in similar proportions, but the ammonia salt has the advantage of being easily dissipated on evaporating the bath and gently fusing, leaving only salts of silver behind, while the nitrate of potash is quite fixed."

Mr. Hardwich's Researches.—Having thus quoted Mr. Ash Hadow's paper, I shall proceed to make the reader acquainted with the results of some most valuable researches as to the nature, properties, and capabilities of this most useful photographic medium, conducted by Mr. F. Hardwich, of King's College, London. I may add, that both these gentlemen well deserve the thanks of every photographer, for the care with which they have studied this important branch of the art, and the generous manner in which they have given the results of their researches to the public. Mr. Hardwich's remarks I quote from the Photographic Journal. This gentleman was led to consider the condition of the film most favourable for the production of pictures to be viewed by reflected light, by a paper translated from the French of M. Gaudin, and published in the Journal of the Photographic Society.

"My attention," he says, "was first directed to the positive process, quite, as I may say, accidentally; and when I was comparatively ignorant of the effects which would be produced by varying the proportions of the ingredients in the sensitive collodion; having adopted Archer's method of iodizing, viz., by adding a certain quantity of a saturated alcoholic solution of double iodides of potassium and silver, I failed, from the alcohol I employed being in too concentrated a state. I had previously rectified it from carbonate of potash, and its solvent power being thus diminished, the amount of iodides taken up was not sufficient for the purpose. When I say 'I failed,' I mean it in the sense that I was not able to obtain good negative pictures, which was the object I had then in view. They were all sadly wanting in 'intensity,' and I found it impossible to 'print' from them with anything like success. However, I soon observed that these unsatisfactory negative pictures looked exceedingly well when viewed as positives by reflected light; there was a nice gradation of tone about them which pleased me, and I adopted the plan of backing them up with black varnish, and preserving them in that form.

"Now at this time, as I said before, I was not aware that I was employing a collodion with an unusually small proportion of iodide; but if I had been, I should not have referred my success in producing positives to that cause. I had never seen it stated in any work with which I was acquainted, that a difference ought to be made in the two cases. The directions I had received were these:—'If you wish to obtain a positive, expose in the camera for half the usual time, and develop with sulphate of iron, to get a bright deposit of metallic silver.' Now the object I have in view is to prove that, if we wish to obtain the best results, we must use not only a different developing fluid, but also a different collodion and a different nitrate bath, in the case of negative and positive pictures respectively. It may be asked, 'What is the inferiority of which you complain in the positives produced by collodion, as it is ordinarily sold?' I answer, it is this: 'That the whole of the picture is not to be seen at once upon the surface of the glass.' Suppose you are taking a portrait, which I think will readily be allowed to be one of the most severe tests of a collodion that can easily be applied, it will be found that the high lights, such as the forehead, the hands, and especially the shirt of the sitter, come out with exceeding rapidity, and in a degree out of all proportion to the time taken by the shadows and half-tints to impress themselves; the consequence of this is, that, stop the action of the light when you will, you do not obtain a perfect picture. After backing up with the black varnish, it will be seen either that the high lights are good, and the rest of the figure almost invisible, or, on the other hand, that the coat, dress, &c., are very clear, whilst the face and hands present an unvaried white and flat surface, without any detail or distinction of parts. These peculiarities do not depend upon the time of exposure, nor in any way on the developing fluid, but simply on the fact that the collodion employed is not capable of giving such a film of iodide of silver as is adapted to produce impressions visible by reflected light.

"Having thus stated the principal difficulties which we have, ordinarily speaking, to encounter, I proceed to show how they may be overcome, and what is the best sensitive mixture for that purpose. In making my experiments, I first prepared simple collodion by dissolving soluble cotton, four grains, in five drachms of ether and three of highly-rectified alcohol. These are the proportions recommended by Mr. Hadow, and I believe them to be the best that can be used. They do not, of course, apply to commercial ether, which already contains a considerable quantity of alcohol. In order to iodize my collodion, I employed iodide of ammonium (purified with care) in four different proportions, viz., four grains to the ounce, two grains, one and a-half grain, and one grain.

"The films produced by these four mixtures, after dipping the plate in the nitrate bath, were very different in appearance; the lowest of all was pale, of a bluish opalescent tint, so transparent that the letters of a newspaper could be read through it with facility; the second somewhat similar; the third of a grayish hue, but still comparatively transparent; the highest of all, viz., the four-grain, creamy and opaque.

"The photographic properties of the films differed considerably; after comparing numerous results, I was satisfied that the two-grain solution was superior to the four-grain for the purpose I intended it; more of the details of the picture were visible at once on the surface of the glass, and there was less tendency to the over-done, flat appearance before complained of. Between the 'two-grain' collodion, the 'grain and a-half,' and 'the grain,' there was likewise a difference, but not to the same extent; on the whole I was disposed to give the preference to the 'grain and a-half,' the last of all requiring too long an immersion in the bath to be used with advantage.

"It was not my intention, at the time I began these experiments, to make any variation in the amount of soluble cotton generally used; I found that four grains to the ounce gave a strong and even film upon the glass, and such being the case, there appeared nothing more to be desired; however, a fact that came under my notice soon afterwards, altered my determination; I began to suspect that the weak solutions of nitrate of silver I was employing did not penetrate the film properly, and consequently I wished, if possible, to remove this objection by diminishing its thickness. The result of the change proved even better than I had anticipated, although the solutions were rather more troublesome to manipulate with; I obtained invariably more perfect pictures; the gradation of tints was now decidedly superior to anything that I had met with before, and although I could not immediately explain the reason, I was satisfied that I had gained an advantage.

"The composition of the collodion which I found after many trials to work the best, is as follows:—Ether, five drachms; alcohol, three drachms; soluble cotton, one and a-half grain; iodide of ammonium, one and a-half grain—instead of this, two grains of each may be used, or even as little as one grain, without very materially affecting the result; but in the latter case the mixture is so fluid, that it is apt to run down the neck of the bottle while attempting to pour it on to the plate. These proportions become very simple when it is considered that they are at once produced by diluting down an ordinary negative collodion rather more than one half, with the proper mixture of alcohol and ether.

"There is one point which I ought to mention: by diminishing the proportion of iodide in the film, and by diminishing the soluble cotton, the sensitiveness is increased. Why is it that these weak films give better half-tones than the opaque ones? Because they are more sensitive to feeble rays of light! I made many experiments to determine this, and I have no hesitation in stating that such is the fact. Neither is it difficult to conceive why it should be so, because, as it has been remarked, the more dilute the solutions from which iodide or chloride of silver is precipitated the more gradual the precipitation, and the more finely divided will the particles of the precipitate be; we can well understand that, such being the case, they ought to be more sensitive to light; we must not, however, confound 'sensitiveness' with 'intensity.' I would use this latter term to signify that the deposit of metallic silver producing the image is thick, and obstructs the luminous rays of light strongly, so as to show well as a negative; 'intensity,' I imagine, relates in some degree to the number of the particles of iodide of silver—in other words, to the thickness of the film; but 'sensitiveness' is independent of this. Now, 'intensity' is required for negative pictures, but it is not required for positives, and therefore, in such a case, I would have as little iodide as possible.

"At the risk of repetition, I will give a short recapitulation of the conclusions which I wish to establish. They are these:—That no proportion of alkaline iodide in collodion beyond that which gives the transparent opalescent film, is adapted to produce a perfect image, visible in every part by reflected light. Allowing that a photographic picture is produced by chemical rays of light acting in various degrees on the several parts of a sensitive surface, it becomes necessary that the particles of iodide composing that surface should be in a peculiar state both as to number and as to fineness of division, in order that the more intense and the feebler rays should work uniformly together, the tendency being in the former, so to speak, to get a-head and outrun the latter; while a diminution in the proportion of iodide assists the action of the feeble rays by producing a more finely-divided deposit, and curbs the violence of the more energetic rays by lessening the number of the particles.

"I shall now proceed," Mr. Hardwich continues, in a subsequent paper, "to consider the proper strength of the nitrate bath and of the developing fluid.

"With regard to the nitrate bath, there were two points of interest to be ascertained,—1st, whether the salt of silver could be used in an accurately neutral condition, and, if so, what are the best proportions; 2nd, the effects of adding nitric acid in graduated quantities.

"Three solutions of nitrate of silver were prepared, of different strengths; A, forty grains to one ounce of distilled water; B, thirty grains; C, twenty grains: all were carefully neutralized, and saturated with iodide of silver.

"On immersing a plate coated with a four-grain iodide collodion in each of these, it was found that with bath C the decomposition of the alkaline salt was imperfect. However, with the proportion of iodide reduced from four grains to two grains, or one and a-half grain, the appearance of the film was the same in each bath, showing that even the lowest proportion of nitrate of silver was sufficient for the conversion of the whole of the iodide of ammonium into iodide of silver.

"A comparison was next made of its photographic properties, the one and a-half grain collodion being used in every case.

"1st. *Sensitiveness.*—Here the difference was not very marked, perhaps the twenty-grain solution had a little the advantage; at all events it was plain that nothing had been lost in this respect by diminishing the proportion of nitrate.

"2nd. *Clearness of Image.*—In every case the image was perfectly clear, in the sense that there was no 'fogging' or reduction of metallic silver on the transparent parts, but there was a difference in the appearance of the 'lights;' when baths A and B were employed, they were always slightly obscured, especially the shirt and forehead of the sitter, by a yellowish deposit of silver, which seemed as if it had been precipitated after the proper development was complete. I conclude that this deposit was derived from the free nitrate of silver on the surface of the film, which being in a more concentrated state in the two former cases, was the more readily acted upon by the developing fluid; however, it may not be that the effect here alluded to will invariably follow when a neutral bath so strong as forty grains to the ounce is used; much depends, no doubt, upon the nature of the developing agent; indeed the two must be associated together, the strength of one varying inversely with that of the other.

"The conclusions arrived at are these, that with the dilute iodized collodion, nitrate of silver in the proportion of twenty grains to the ounce, gives equal sensibility and in every respect the same perfection of image as when used of greater strength; besides this, it has the merit of economy and superior cleanliness of manipulation; if the proper precautions are observed, such a bath will remain constant in its action for a length of time.

"Before proceeding to the developing fluid, there yet remains to be considered, as originally proposed, the effect of adding nitric acid in graduated quantities to the neutral nitrate bath; my experiments in this direction are, I am sorry to say, as yet incomplete; however, two or three facts of importance are manifest, viz., that it is impossible to lay down any general rule as to what the effect of adding the acid will be, unless we take into account all the other circumstances of the case; no doubt there will invariably be a loss of sensitiveness, but whether or not advantages will be gained in other respects, seems to depend upon further considerations. When collodion positives are taken by solutions modified as I have proposed, it will be found that the smallest amount of free acid, even such as cannot at once be detected by test-paper, will sadly injure the 'half-tones' of the picture.

"On the other hand, many photographers advocate the use of nitric acid, and state that they obtain a better result by means of it.

"In explanation of this seeming discrepancy I would suggest (and the views I entertain are borne out by my experiments as far as they have gone), that the amount of free nitric acid which may be added to the bath with impunity depends mainly upon the strength of the solution of nitrate of silver; strength of bath is favourable to reduction, nitric acid is opposed to it, consequently the two, to a certain extent, balance each other. But besides this, I am inclined to think that something depends upon the thickness of the film of iodide of silver; perhaps it may be that the particles of iodide being less in number, are more easily attacked; but, at all events, it seems necessary to regulate the acid, both in the bath and the developing fluid, with greater care when weak films are employed than under contrary conditions.

"It is important then, and indeed essential, that the dilute nitrate bath should be preserved accurately neutral; this may easily be effected by adding a little carbonate of soda and so setting free carbonate of silver, which can be allowed to remain continually at the bottom of the bottle in which the bath is kept; if, however, iodide of ammonium is used in the collodion, this plan does not succeed, because nitrate of ammonia, which will then be formed in the bath, has the property of dissolving carbonate of silver and forming with it an alkaline solution; in that case it is better to keep a piece of blue litmus-paper always in the solution of nitrate, and when the colour is perceived to be changed by the small amount of acid liberated by the free iodine in the collodion, to add ammonia graduated to fortieths of a minim until the evil is removed.

"Having now finished what I have to say on the subject of the nitrate bath, it only remains that I should speak of the development of collodion positives, in order to complete my paper. The deposits which constitute the light portion of these pictures consist, in all cases, excepting where the bichloride of mercury is used, of metallic silver; but it may be useful to class them under two heads, according as they do or do not possess metallic lustre.

"The first is a surface bright and sparkling like frosted silver, very white when produced in perfection, but with occasionally a greyish or tinfoil hue.

"The second is dull and without lustre, of a whitish tint slightly inclining to yellow or grey; there is no appearance of a metal about it, the colour being more like that of a piece of chalk.

"These two varieties require exactly opposite conditions of developing fluid to produce them. From what I can gather from my own experiments, and from the observation of others, it would seem that the first is obtained by means of a reducing agent, checked, as it were, in its action by the presence of a strong acid, consequently the development proceeds slowly and gradually, and the particles of silver are large and crystalline; on the other hand, the second variety results when the action of the developer is sudden and violent, no impediment being offered by the presence of acid except in minute quantity. The particles of metallic silver are here smaller than before, and being comparatively amorphous, they reflect light in a different manner. The distinction in the two cases, if these views are correct, lies in the amount and strength of the acid used; in the one it is simply sufficient to whiten the picture slightly by preventing the precipitation of oxide; in the other, being increased in quantity, it tends to retard the development as well. In conducting these experiments the action of several different developing agents was compared, viz., pyrogallic acid, the same with subsequent whitening by bichloride of mercury, protonitrate of iron, and protosulphate of iron.

"1st. *Pyrogallic Acid.*—This gives, under certain circumstances, a beautifully white deposit of silver, free from lustre; it should be used in the proportion of three grains to the ounce, with a small quantity of nitric acid; if too much of this substance be added, the deposit is more metallic, but the half-tones are not properly brought out, so that pyrogallic acid is not adapted to produce what I have termed the first variety; so also it does not succeed when the proportion of nitrate of silver in the bath is reduced to twenty grains to the ounce; in that case the development becomes imperfect in parts of the plate, and large patches of a blue or greenish colour are seen.

"2nd. *Pyrogallic and Acetic Acid, with subsequent Whitening by Bichloride of Mercury.*—I was unsuccessful in my attempts to produce good pictures by this plan; the colour of the image was not sufficiently white, but had invariably a bluish tint, which was particularly unpleasant; other photographers, I am aware, have produced excellent results with bichloride of mercury, and it may be that the extreme tenuity of the film I employed was one cause of the blueness and transparency. Another objection appeared to be that the details of the picture were slightly injured by the action of the bichloride, and the whole image reduced to a certain extent in intensity; this was more apparent after blackening by means of ammonia, and then again whitening a second time.

"3rd. *Protonitrate of Iron.*—This substance is peculiar in producing an image of brilliant metallic lustre, without the addition of any free acid, hence it may at first sight seem to be an exception to the observations that have just been made on this subject; it is remarkable, however, that protonitrate of iron should be so feeble a reducing agent when compared with the corresponding sulphate; probably the reason may be, that in passing into the state of persalt, a portion of the oxygen required is furnished by the decomposition of the nitric acid itself, and hence less would be abstracted from other sources. In experimenting with proto-nitrate of iron, I found a difficulty sometimes in bringing out the half-tones of the picture properly. To obviate this, it is advisable to use the solution of the salt in as concentrated a state as it can be procured, and to increase the proportion of nitrate of silver in the bath, if required, from thirty-five grains to forty grains to the ounce.

"With the dilute nitrate bath of twenty grains to the ounce, protonitrate of iron failed entirely to develop the image, thus affording most conclusive proof of the close relation which the strength of the bath bears to the energy of the development.

"4th. *Protosulphate of Iron.*—This salt appears better adapted for the purpose than either of the others when the twenty-grain bath is employed. In order to obtain the tint which has been characterized as a dead white with absence of metallic lustre, it must be used of such a strength that the picture comes out almost instantaneously in all its details; it occurred to me at first that the gradation of tone would be injured somewhat by this violent method of proceeding, but I did not find on trial that such was the case; neither is there any indication of fogging or over-development if the solution be poured off from the plate tolerably quickly.

"The proportions I have been in the habit of using are these:—Protosulphate of iron pure, fifteen to eighteen or twenty grains; acetic acid (glacial) minims viij.; distilled water one ounce.

"In the place of the acetic acid, strong sulphuric acid minim half, or nitric acid minim a quarter, with fifteen drops of alcohol may be used; the alcohol certainly has the effect, as has been stated, of causing the solution to flow more evenly; but it appeared to me, that if present in too large quantity, the liability to 'specks' and 'dirty marks' was increased.

"If the solution of protosulphate is in too concentrated a state, it will be difficult to pour it on the plate sufficiently quickly to cover the whole surface before the action begins; in such a case, after fixing with the cyanide, curved lines will be seen, such as would be produced by a wave of fluid flowing forwards and resting for an instant at a particular spot.

"On the other hand, if the solution is too dilute, the image becomes slightly grey and metallic on drying.

"For fixing the picture by removal of the unaltered iodide of silver, cyanide of potassium appears preferable to the hyposulphite of soda; it may be used of such a strength as will clear the plate gradually in about half a minute or so, and is easily washed away by pouring a stream over the plate for a short time.

"For 'backing up' I employ two varnishes, both of which dry speedily; the solvent is different in the two cases, and that of the black japan does not appear to act upon the transparent layer beneath. A complaint is sometimes made that collodion positives do not show to advantage through the glass, but I have not myself been able to distinguish at all between the two sides, excepting in cases where the picture was slightly over-exposed.

"With regard to the time required for taking a portrait on a tolerably bright day, as giving some indication of what the degree of sensitiveness of the plates might be, I would say that with a Ross's portrait lens of two and a quarter inches, having a diaphragm of an inch and three quarters aperture, an exposure in the camera of two to three seconds is the average; when distant objects are taken with the full aperture of the lens, it is hardly possible to remove and replace the cap with sufficient quickness."

Mr. Horne's Process.—Mr. Horne has been one of the earliest and most successful operators, and has published an account of the particular manipulations required in the collodion process. By his permission, I am enabled to give the process he adopts in his own words. As regards the choice and preparation of the plate itself, the operator cannot do better than follow the directions of Mr. Hardwich, which I have already recorded. The plate selected, having a clean and perfectly dry surface, and taking care to handle it as little as possible, the next operation is that of

"*Coating the Plate.*—Taking it from the clean dry leather in which it has been wrapped, there are several ways by which the iodized collodion may be applied, some preferring a piece of India-rubber fastened to the back as a handle, others supporting it on the ends of the fingers of the left hand (Fig. 64); while others, again, content themselves by sacrificing a small portion of one corner, or by the use of an instrument called the pneumatic plate-holder, which appears to answer well. But whichever plan is adopted, the plate must be held by the left hand perfectly horizontal, and then with the right a sufficient quantity of collodio-iodide should be poured into the centre, so as to diffuse itself equally over the surface. This should be done coolly and steadily, allowing it to flow to each corner in succession, taking care that the edges are all well covered. Then gently tilt the plate, that the superfluous fluid may return to the bottle from the opposite corner from which the plate is held. At this moment the plate should be again brought into a vertical position, when the diagonal lines caused by the fluid running to the corner will fall one into the other, and give a clear flat surface. To do this neatly and effectually, some little practice is necessary, as in most things; but the operator should by no means hurry the operation, but do it systematically and quietly, at the same time not being longer over the operation than is actually necessary, for collodion, being an ethereal com-

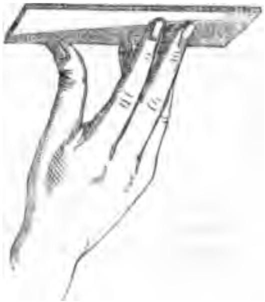
Fig. 64.

pound, evaporates very rapidly. Many operators waste their collodion by performing this operation in great haste; but haste is not necessary, for an even coating can seldom be obtained if the fluid is poured on and off too rapidly; it is better to do it steadily, and submit to a small loss from evaporation, and at any future time, if the collodion becomes too thick, to thin it with the addition of a little fresh and good ether.

"*Exciting the Plate.*—Previous to this it is necessary to have the bath ready, which is made as follows:—

Nitrate of silver	10 drachms.
Distilled water	20 ounces.
Iodide of silver	5 grains.

Dissolve and filter.

"The object of putting the iodide of silver is that the nitrate may be saturated with it, or the plates would otherwise be robbed of a certain portion. Now to saturate the nitrate properly, it is necessary the iodide should be freshly precipitated, therefore the best plan is to proceed as follows:—

"Dissolve the ten drachms of nitrate of silver in two ounces of distilled water, and add to this five grains of iodide of potassium previously dissolved in about two drachms of distilled water. Upon mixing these, the iodide is thrown down, and redissolved by the concentrated solution of silver, when the remainder of the water, namely, eighteen ounces, may be added, and the solution very carefully filtered.

"The quantity of this fluid necessary to be made must depend upon the form of trough to be used, whether horizontal or vertical, and also upon the size of plate. The trough used by the writer is the vertical, though many still prefer the former, and attach, as before described, a piece of India-rubber to the back of the plate as a handle whilst applying the collodion, and to keep the fingers from the solution whilst dipping in the bath. With the vertical troughs a glass dipper is provided upon which the plate rests, preventing the necessity of any handle or the fingers going into the liquid. Having then obtained one or other of these two, and filtered the liquid, previously free from any particles of dust, &c., the plate is to be immersed in it steadily and without hesitation, for if a pause should be made at any part, a line is sure to be formed, which will print in a subsequent part of the process.

"The plate, being immersed, must be kept there a sufficient time for the liquid to act freely upon the surface, particularly if a negative picture is to be obtained. As a general rule it will take from two to four minutes, varying with temperature and make of the collodion. In very cold weather, or indeed anything below 50° Fah., the bath should be placed in a warm situation, or a proper decomposition is not obtained under a very long time. Above 60° the plate will be almost certain to have obtained its maximum of sensibility by two minutes' immersion, but as the plate cannot injure by remaining a longer time in the bath, it is better in all cases, when a negative picture is required, to give time for the whole of the iodide in the collodion to be thoroughly acted on by the nitrate of the bath.

"To facilitate the action, let the temperature be what it may, the plate must be lifted out of the liquid two or three times, which also assists in getting rid of the ether from its surface. If this is not thoroughly done, a uniform coating cannot be obtained; but on no account should it be removed until the plate has been immersed about half a minute, or marks are apt to be produced.

"Having obtained the desired coating, the plate is then extremely sensitive to white light, and every precaution should be taken to exclude ordinary daylight. The best way to do this is to hang over the window two or three thicknesses of yellow calico, by which means the light which passes through will be amply sufficient for manipulation, and at the same time produce no injury to the sensitive plate. If this cannot be done, the room must be closed against any portion of daylight, and a candle alone employed, placed however, at a distance from the operator, to give the requisite light.

"The plate thus rendered sensitive must then be lifted from the solution and held over the trough, that as much liquid as possible may drain off previous to being placed in the frame of the camera, otherwise the action will not be equal over the whole surface. It must not be allowed to dry, however; but, in order to obtain its full maximum of sensibility, it should be damp without superfluous moisture. It is thus imperative that the exposure takes place within a few minutes after removing the plate from the bath. This renders collodion of very little value for taking views, as in such situations we cannot command the use of a dark-room.

"The question is often asked—How soon after the coating the plate with collodio-iodide, should it be immersed in the nitrate bath? We have said the time of immersion is dependent upon temperature and make of collodion, so likewise must we be governed as to time before immersion. To make collodio-iodide or xylo-iodide—for, chemically speaking, there is no difference in the two—it is necessary that the ether should contain a certain quantity of alcohol, or the different articles are not soluble; therefore, if we take a fresh bottle and coat the plate from this while it contains its full dose of ether, and with the thermometer ranging between 60° and 70°, the evaporation of this article will be very rapid, and consequently a tough film soon formed; but if, on the other hand, we are using an article which has been in use some time, and many plates, perhaps, coated, the proportion of alcohol will be much greater, and not being of so volatile a nature, will necessarily take a longer time to acquire the necessary firmness for immersion. Hence it is evident we must be guided by circumstances. If, for instance, after coating a plate, we find on immersion it does not colour freely, we have then reason to suppose the plate has not been immersed sufficiently quick; but if, on the other hand, we find the film very tender, and it cracks upon drying, then we have reason to know that plates prepared from that bottle must not be immersed quite so soon. The larger the proportion of alcohol the more tender the film, but the more sensitive will be the plate, and the quicker and more even will be the action of the bath.

"The next question also often asked is—How long must be the exposure in the camera? a question more difficult to answer than the last, and which practice alone can determine, combined with close observation of those parts which should be the shadows of a picture. If, for instance, in developing, we find those parts less exposed to the light than others develop immediately the solution is applied, then we have every reason to suppose the exposure has been too long; but if, on the contrary, they develop very slowly, we have proof that the time allowed has not been sufficient to produce the necessary amount of action. In a good picture we should see first the whites of the dress appear, then the forehead, after which we shall find, if the light has been pretty equally diffused, the whole of the face and then the dress.

"Much will, of course, depend upon the arrangement of light, for if the sitter is not placed in a good aspect, by which is meant a good diffused light, the prominent parts only will come out; in other words, to produce the necessary amount of action to obtain the others, the high lights are so overdone that the picture prints raw and cold.

"Can I produce portraits at my drawing-room window? This is another common question, and the reply must necessarily be, Yes, if you have sufficient light, and can so place your camera that the sitter may be pretty equally illuminated, and not one half receiving nearly all the light; if it does, one side may be amply developed and the other scarcely visible.

"In cases of this description the necessary effect may often be produced by placing a white screen so as to reflect a portion of light upon the darkened side; but, upon the whole, a light of this character is better adapted for producing positive than negative pictures upon glass.

"*The Development of the Image.*—To effect this it must be taken again into the room where prepared, and with care removed from the slide to the levelling stand. It will be well also to caution the operator respecting the removal of plate. Glass, as before observed, is a bad conductor of heat; therefore if, in taking it out, we allow it to rest too long on the fingers at any one spot, that portion will be warmed through to the face, and as this is not done until the developing solution is ready to go over, the action will be more energetic at those parts than at others, and consequently destroy the evenness of the picture. We should, therefore, handle the plate with care, more as if it already possessed too much heat to be comfortable to the fingers, and we must therefore get it on the levelling stand as soon as possible.

"Having then got it there, we must next cover the face with the developing solution. This should be made as follows:—

Pyrogallic acid	10 grains.
Distilled water	5 ounces.
Glacial acetic acid . . .	1 drachm.
Spirits of wine	½ a drachm.

Mix and thoroughly filter.

"Now, in developing a plate, the quantity of liquid taken must be in proportion to its size. A plate measuring five inches by four will require half an ounce, less may be used, but it is at the risk of stains; therefore we would recommend, that half an ounce of the above be measured out into a perfectly clean measure, and to this from eight to twelve drops of a fifty-grain solution of nitrate of silver added.

"Pour this over the surface, taking care not to hold the measure too high, and not to pour all at one spot, but having taken the measure properly in the fingers, begin at one end, and carry the hand forward; immediately blowing gently upon the face of the plate, which has the effect, not only of diffusing it over the surface, but causing the solution to combine more equally with the damp surface of the plate; it also has the effect of keeping any deposit that may form in motion, which if allowed to settle, causes the picture to come out mottled. A piece of white paper may now be held under the plate, to observe the development of the picture; if the light of the room is adapted for viewing it in this manner, well; if not, a light must be held below; but, in either case, arrangements should be made to view the plate easily whilst under this operation, a successful result depending so much upon obtaining sufficient development without carrying it too far.

"In some instances it is better not to mix the nitrate of silver solution with the pyrogallic until after the latter has been poured over the plate, but in no case must it be mixed on the plate, the solution must be poured off into the measure and the nitrate added. In this way we can judge better of the intensity of the picture, for when the solution is off, the plate can be held up to the light and the image viewed through. Care should be taken that the nitrate of silver solution is free from deposit.

"The author has also found a weak developing solution, as given above, far more successful in obtaining gradation of tone than when stronger, for, in the latter case, the action will be very energetic on those parts reflecting the most light, and, consequently, become overdone before other portions, such as dress, &c., have become sufficiently visible. The addition of an extra portion of nitrate of silver will be found to improve the tone, but this may be effected also without adding it to the pyrogallic solution; and, in many instances, it will be found a better plan to re-dip the plate in the bath, after exposure in the camera, particularly if any considerable time has elapsed between the excitement of the plate and development of the picture, for the plate having dried unequally does not allow the same uniform development as when well moistened over the surface.

"As soon as the necessary development has been obtained, the liquid must be poured off, and the surface washed with a little water, which is easily done by holding the plate over a dish and pouring water upon it, taking care, both in this and a subsequent part of the process, to hold the plate horizontally, and not vertically, so as to prevent the coating being torn by the force and weight of the water.

"*Fixing the Image.*—Which is simply the removal of iodide from the surface of a plate, is effected by pouring over it, after the water, a solution of hyposulphite of soda, made of the strength of eight ounces to a pint of water. At this point daylight may be admitted into the room; and, indeed, we cannot judge well of its removal without it. We then see the iodide gradually dissolve away, and the different parts left more or less transparent, according to the action of light upon them.

"It then only remains to thoroughly wash away every trace of hyposulphite, for, should any of this salt be left, it gradually destroys the picture. The plate should, therefore, either be immersed with great care in a vessel of clean water, or, what is better, water poured gently and carefully over the surface. After this it must be put in a proper place to dry, or held before a fire.

"It may be as well to state, any clean filtered water will answer for washing, distilled being only required for the solutions of nitrate of silver, &c.

"Having, by the foregoing means, obtained and fixed a negative photographic image on glass, and which is capable of producing positives upon paper by the ordinary photogenic printing; it is as well, previous to obtaining these, to render the tender film of collodion less liable to injury. This is best accomplished by—

"*Varnishing the Plate.*—There are two kinds of varnishes which may be used for this purpose—the spirit and turpentine; of the latter kind the gum-dammer answers best, and indeed the only objection to its use is, that it requires forty-eight hours to dry—whereas with the former, which consists of spirit and a great variety of gums, the plate may be printed from within a few minutes. Some amount of care is necessary in the use of the latter, for if it is poured on the plate cold, the gums chill, and the picture is rendered opaque; therefore the best plan of proceeding is as follows:—

"Hold the back of the plate to a fire until warm through, care being taken not to make it too hot, or the varnish will not run properly; then pour the varnish on in the same manner as the collodion, returning the superfluous liquid to the bottle. Hold the plate again to the fire to drain off the spirit, when a beautiful surface will be obtained, making it difficult, at first sight, to judge which side has been varnished.

"The dammer varnish may be applied cold, care being taken to make it very thin, either with turpentine or camphine, otherwise it will be days before it is sufficiently dry to print from.

"There is also another kind of varnish which has been recommended by Dr. Diamond, viz., gum-amber dissolved in chloroform. This is used by many photographers, as it can be put on cold, and yet it dries directly upon evaporation of the chloroform, otherwise it possesses no advantage over the spirit, and is necessarily much more expensive.

Positive Pictures upon Glass.—Hitherto we have described the method of producing negative pictures only, but by slightly varying the process in developing the collodion pictures, most beautiful positives, equal to Daguerreotypes, may be obtained, and without their metallic reflection. These pictures are strictly, positive, for, when held to the light, they scarcely show as a negative. To produce them, a much shorter time is necessary for a sitting than for the production of a printing negative. They also require a modification in the development, that as bright a surface may be obtained as possible.

"It was shown by the author, in the early days of collodion, that this result might be obtained, to a certain extent, by mixing with the pyrogallic solution a very small quantity of nitric acid; but it has since been proved by Mr. Fry and others, that a better result may be obtained by the use of proto-sulphate and proto-nitrate of iron.

"The former salt is readily obtained, and in a very pure form. It should be used as follows:—Proto-sulphate of iron, ten grains; distilled water, one ounce; nitric acid, two drops. To develop the image, pour the above over the plate, taking care not to carry the development too far.

"The proto-nitrate may be obtained either by double decomposition, as recommended by Dr. Diamond, or by dissolving sulphuret of iron in dilute nitric acid, as recommended Mr. Ellis. The latter, being the most economical, we will describe first.

"To one ounce of nitric acid, and seven of water, add a small quantity of sulphuret of iron broken into fragments. Stand the vessel aside, that the sulphuretted hydrogen may escape, and the acid become saturated with iron. Pour off the liquid, and filter. Boil it again in a Florence flask to get rid of the sulphur, and again filter, when a dark green liquid will be obtained, which is the proto-nitrate of iron. This should be kept in well-stoppered bottles, and from air as much as possible, to prevent its changing into a per-nitrate, in which stage it is quite useless as a photographic agent.

"To develop the picture, mix one part of the above proto-nitrate with three of water, and apply it to the plate in the ordinary way, when a most beautiful clear image will be obtained.

"Dr. Diamond's method we take from the Art Journal. 600 grains of proto-sulphate of iron are dissolved in one ounce of water, and the same quantity of nitrate of baryta in six ounces of water; these being mixed together, proto-nitrate of iron and sulphate of baryta are formed by double decomposition; the proto-nitrate of iron being in solution, and the sulphate of baryta precipitated, the latter being easily removed by filtering the solution.

"The negative image being developed, a mixture of pyrogallic and hyposulphate of soda, which has undergone partial decomposition, is poured over the plate, which is gently warmed. Upon this the darkened parts are rendered brilliantly white by the formation of metallic silver. This picture being backed up with black velvet, assumes the air of a fine Daguerreotype, without any of the disadvantages arising from the reflection of light from the polished silver surface. We have also seen a similar effect produced by Mr. Fry and Mr. Berger, by the use of the proto-sulphate of iron solution and pyrogallic acid. The image is first developed by the iron solution, which is then poured off, and another solution of pyrogallic is poured on, until the effect is produced. The pictures are fixed with the hyposulphite in the usual method."

The Author's Process.—I have now to offer some remarks on the collodion process as practised by myself, and I commence by reiterating my caution in favour of care and cleanliness, which is the motto it is impossible to impress too strongly on the mind of the reader. Before commencing operations, have everything as nearly as possible, in the following state:—The glass house must be scrupulously clean, and free from slops and dust; care must be taken that no ray of white light gains admittance through any chink or hole—the door will be the part most subject to this; the light used should be obtained through a piece of orange or red glass—a foot square will be quite large enough—and it should not face the sun. It may be necessary in very bright weather to have a curtain of yellow calico on a roller, so that it may be used or not, as may be required. There should be a deep tray to receive the washings, and this should have a waste-pipe, if possible, to prevent the accumulation of slops; the tray and water-tap should be as nearly as possible under the light, and if the water has to fall from any height, so as to fall with force, it will be necessary to tie a piece of old linen on the opening of the tap—by this means you will obtain a plentiful supply of water, which will fall so gently as scarcely to be felt by the finger; by this precaution you will not run any danger of washing off the collodion film. It will also be a great advantage to have the tap fastened to the supply-pipe by a couple of feet of vulcanized India-rubber, or flexible gutta-percha tubing, so that the plate especially a large one) may be supported on the tops of the thumb and fingers of one hand, while the other can swill the water over the surface with ease in every direction.

Have your exciting bath so placed that the yellow light may *rake* the surface of the plate when you lift it out to examine the state of the iodized and excited collodion film, but this should never be done until the plate has been at least a minute in the bath. You must also take care that the bath is sufficiently far away from the washing tap to prevent the risk of splashings from the latter when washing the plate. The developing glass should have a small stand for itself, covered with a sheet of blotting-paper folded half a dozen times, to be renewed when it becomes wet through. The collodion bottle should stand on another shelf, and the vessel holding the solution of hyposulphite of soda or cyanide of potassium should occupy another shelf—this must never be used for any other purpose, neither should the hypo-vessel ever be placed any where else—this latter shelf should be much lower than the others. You should have a towel for the hands, another for wiping out the slide after each plate—but "*papier Joseph*" is better—and a cloth for wiping up all slops. The developing-room I consider most convenient would resemble the following sketch (Fig. 65), supposed to be made when looking down from the roof—the shelving being about the height of a common table or a little higher:—

A, the window of orange glass; B, the shelf for the developing-bottle and vessel; C, the water-tap; D, the waste-pipe; E, the washing-tray; F, the main shelf or bench; G, the exciting bath; H, the shelf for collodion bottles; I, shelf on which may stand the dark slide when not in use; J, the shelf for the hyposulphite vessel; K, the body of the room; L, a curtain running on a rod with rings, to be drawn across after the door is shut; M, the door; N and O, hooks for towels. The above will be found to be a most convenient dark-room; and it may be as well to say here, in reference to such places in general, never allow bottles, or any other articles *not in use*, to remain on the shelves or in the dark-room; have everything in its proper place, and have everything put away, and the dark-room cleared and *swept* out after the work is done for the day, so that it may be clean and *free from dust* for the next day's operations.

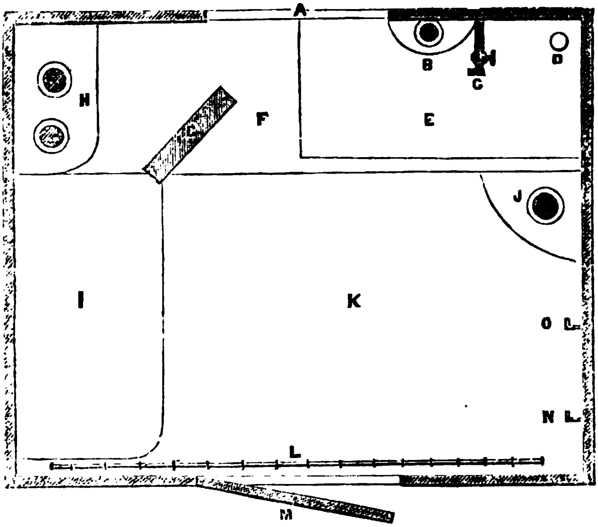

Fig. 65.

Preparing the Glass.—As everything depends on a clean glass, I adopt this mode of preparation, which differs somewhat from that recommended by Mr. Hardwich:—I mix up some Tripoli powder or whiting, with one part liquor ammonia, two parts alcohol, and three parts water; dip a piece of clean cotton wool into this mixture, and proceed to cover the surface of a glass plate already washed and dried. Do this in circles, and with some degree of force at first, leaning less weight as you are about to finish; treat half-a-dozen or more glasses in the same way. Put them to dry with their faces (the surface covered with the Tripoli, &c.) next the wall, and when dry take a second piece of cotton-wool, and by briskly drawing it over the surface remove the dry dust left on the latter by the evaporation of the Tripoli mixture, and from off the edges also; then take another clean and *dry* piece, and finish off with the greatest care. As each is finished, place it in a box with grooves, and take care that the faces are all in the same direction. I should recommend the clean side towards the back of the box or from you, because, if you should not have an empty box, you would place them resting on the collodion shelf with the *clean side next the wall;* then filter your bath of nitrate of silver, the developing solution, and the collodion (the latter must be filtered through a papier Joseph). It will answer as well, in most cases, if the collodion is gently decanted from the bottle, holding it into another (previously washed out with a small quantity of ether), keeping back the bottom portion, which will contain any portions of undissolved cotton, &c., that may be present. The collodion should have been mixed some hours before use; if even a day it would be all the better.

Coating the Glass.—Supposing now that you are about to operate, you will proceed as follows:—Go into the dark-room, and wash out the glass you intend to use for developing. A glass called a precipitating glass, such as is here figured (Fig. 65), is the best for this purpose. Put the requisite amount of developing solusion in it; then take the bottle holding the collodion that you intend to use, and, taking out the stopper, insert very carefully the point of one of your fingers so as to remove any portion of dry collodion that may remain there. Take care that there is not any more remaining about the neck or body of the bottle, or anything else that might fall on the glass plate. Taking a glass plate on a holder, or, what is far better, the tips of the fingers of the left hand, pour gently, and without any *haste* or *flurry*, a sufficient quantity of collodion on its clean surface. There are many methods of doing this, but the most successful that I know of is to pour the collodion on the plate thus (premising that you are holding the glass on the fingers of the right-hand as in Fig. 64):—Commence at A (Fig. 67), and as you pour on the collodion, allow it, by inclining the glass, to take the course pointed out by the line proceeding from A to E. In doing this, do it slowly and evenly, and recollect that it is not necessary to allow, or, more properly speaking, to wait, for the collodion to run right up to the corner, for when it arrives near B, that corner of course will be the lowest; but in altering the inclination so as to cause it to flow towards C, we do not raise B but depress C until B and C are about equal; that being the case, the *side* of the plate between B and C becomes the lowest, and by the time the collodion arrives near the corner C, it will have flowed fully up to B; the same action takes place between C and D, and so on. The advantage gained is, that the collodion never flows *back again* over a part *already coated.*

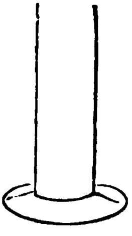

Fig. 66.

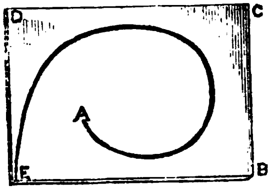

Fig. 67.

The Nitrate Bath.—By a little practice the reader will be able to coat any sized plate. Return the surplus collodion into the bottle from E, rapidly sliding the fingers up to C, E resting on the mouth of the bottle, and thus preventing any unequal evaporation from the parts which would be otherwise over the points of the fingers; and when the collodion has nearly all run off, move the plate backwards and forwards a few times, so as to prevent the formation of any lines in the film of collodion; in other words, change the position of the plate from Fig. 68 to Fig. 69. When the collodion ceases to drop, and the film becomes pretty well set, place the plate on the dipper, and (having previously skimmed the surface of the nitrate of silver solution in the bath with a small strip of blotting-paper) proceed to immerse the dipper and plate slowly and evenly, recollecting that if you make a stop or hesitate for a moment, you surely spoil the plate. The latter once in the exciting bath, leave it there and carefully wipe out the slide, then covering the bath

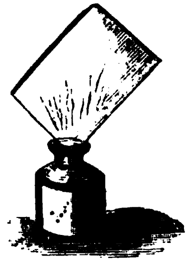

Fig. 68.

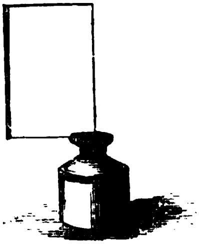

Fig. 69.

with a light-proof cover, open the door of the dark-room, and proceed to focus and arrange the sitter or object to be copied.

The plate may be coated with collodion and immersed in the bath without the necessity of having the door of the dark-room closed, as the sensitive iodide of silver is not formed on the instant of immersion; but in this case it will be necessary to cover the bath with a light-proof cover, or to shut the door immediately.

Placing in the Camera.—Having obtained the proper focus and adjustment of the object to be copied, put the cap on the lens, and remove the ground glass, then, going into the dark room close the door, and draw the curtain. If a minute at least has elapsed since the immersion of the plate, draw it out of the bath, and examine the surface to see if all greasiness has disappeared, otherwise the plate will be all mottled and streaky. When the surface of the plate appears smooth and even, dip it and withdraw it two or three times afterwards. Then allow it to drain for nearly a minute, allowing it to become nearly dry, and never attempting to take a collodion picture while the plate is dripping;—this is an essential point, and should be strictly attended to if a good picture be desired. When the plate has been sufficiently drained, place it carefully in the dark slide; placing the slide gently in the camera, pull the shutter up quietly, and uncover the lens for the proper time. Take especial care not to push the shutter down with a bang, or with force, that being sure to cover the plate with spots and stains. I have seen an amateur hitting and thumping the shutter of his dark slide when it stuck from being swollen by wet, or some other cause, and I need scarcely add, that the resulting picture was a brilliant specimen of spots and messes. In fact, every operation in the collodion process should be performed as if you were working in the den of a sleeping tiger!

Developing.—Upon entering the dark-room with the exposed plate, previous to development, gently shut the door and draw the curtain (it is better to have the curtain tacked permanently across the inside of the door, and without plaits—in this case it must be pushed on one side when entering or leaving the dark-room), then place the slide, leaning against the wall, on the left hand, taking care not to knock it, and looking round to see if your developing glass contains the required solution, and that everything else is ready; take out the back of the slide, and holding the upper part of the latter in the left hand, lean it gently over until the excited plate falls out against the thumb and spread fingers of the right, placed in a proper position to receive it. By lowering the hand, the plate becomes level, and may be lifted away from the dark slide at once on the tops of the fingers. You next proceed to transfer it to the left hand, and take up the developing-glass in the right; then slowly, and without hurry, but at the same time evenly and without hesitation, commence to pour the solution on the surface of the plate; this will require no little practice, and should be done in such a manner that the plate will be just covered by the time all the solution has left the glass—the former should flow evenly over from end to end. To cover a large plate well, proceed thus:—Let the corners A B be lower than C D, but in the same horizontal line in the direction from A to B, or looking at the side of the plate (Fig. 70), then commence to pour on to the plate at C, and draw the glass backwards and forwards as you go down the plate (Fig. 71). It will not be necessary to go over

Fig. 70.

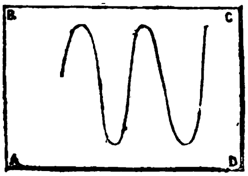

Fig. 71.

more than half the plate with the developing glass, as the amount of liquid will by that time have flooded the whole. Then, by moving the hand and fingers, cause the liquid to flow from end to end, and from side to side, pouring it back into the glass and on to the plate again, until the desired amount of intensity and development are obtained; this may be ascertained by looking through the plate when the developing solution has been poured back into the glass.

When fully developed, wash it well before using the fixing agent. This is the more necessary when hyposulphite of soda is employed, as that salt would be decomposed by the presence of the acetic or other acid used, and by throwing down sulphur injure the brilliancy of the negative. After all traces of the iodide of silver have disappeared, the plate must then be well washed with plenty of water, covering it fully each time, swilling it about on the surface for a few moments, and pouring it off again; then set it up to dry. The lower edge should rest on a strip of blotting-paper. When dry, examine it for a sort of whitish powder, something like frost; should this appear on the surface, it is owing to the presence of hyposulphate of soda, and shows that the plate was not sufficiently washed. Should the plate be perfectly free from any such appearance, it may then be varnished. This is done by slightly warming the plate, covering the surface with varnish as you did with collodion, and, returning the excess to the bottle, holding the plate to the fire until it dries without chilling. The negative, or positive, is now finished, and by carefully following the preceding directions, a good picture should be the result; but if not, we must endeavour to find out the cause.

Mr. Hardwich's Formulæ.—These remarks on the manipulation which has been adopted in Mr. Fenton's establishment I would have followed by my own formulæ for preparing each of the solutions required, but Mr. Hardwich has treated this branch of the subject so fully and so ably in his "Chemistry of Photography" that I willingly avail myself of his permission to quote this and other portions of his book; and I do so the more readily as it would be nearly a matter of impossibility for me to do the subject justice otherwise than in his own words. That the reader may understand my meaning more fully, I may quote the passage from the preface to Mr. Hardwich's work, in which he mentions my connection with his experiments. "*I am also indebted*," he says, "*to Mr. Sparling for repeating many of my experiments upon a larger scale, and carefully chronicling the results.*" Such being the case, I can scarcely do otherwise than give the formulæ, the result of these experiments, in Mr. Hardwich's words, while I acknowledge his courtesy in granting me permission to do so.

As there is much difficulty in ascertaining the proper strength of the materials employed, Mr. Hardwich goes at considerable length into the question, and in a future page I may give the substance of his researches. His formulæ we shall quote in the order in which he gives them:—

"FORMULA FOR SOLUTIONS FOR DIRECT POSITIVES.—The solutions are taken in the following order:—The collodion; the nitrate bath; developing fluids; fixing liquids; whitening solution.

"*The Collodion.*

Purified ether, sp. gr. ·720	5 drachms.
Purified alcohol, sp. gr. ·825	3 „
Pyroxyline	2 to 3 grains.
Pure iodide of ammonium	2 grains.

Or,	Rectified ether, sp. gr. ·750	6 drachms.
	Spirits of wine, sp. gr. ·836	2 „
	Pyroxyline	2 to 3 grains.
	Iodide of potassium	2 to 3 „

"The exact quantity of pyroxyline required cannot be stated, since some samples produce a more glutinous solution than others. The rule is to keep the texture of the film slight. If the quantity specified yields a solution fluid like water, and running down the neck of the bottle in the attempt to pour it on the plate, it may be increased.

"The appearance of the film, after dipping in the bath, is a guide to the proper quantity of ingredients; it should be blue and transparent. If it is pale, increase the quantity of pyroxyline, at the same time with that of the iodide.

"The iodides of potassium, ammonium, or cadmium may be used. Collodion iodized with the cadmium salt possesses great keeping qualities; but the writer prefers the alkaline iodides, and especially the iodide of ammonium, if it be pure. Iodide of potassium does not dissolve in quantity greater than two grains to the ounce if the ether and alcohol are highly rectified.

"With regard to the length of time this collodion can be kept in working order, everything will depend on the condition of the ether. If recently distilled, probably the colour will scarcely have passed the orange-yellow stage at the expiration of a fortnight, or even with iodide of potassium three weeks or a month. A lemon-yellow tint does no injury to the most delicate film, but when the colour reaches to a decided brown, the iodine may be removed.

"The writer does not, from experience, advise keeping a stock of the dilute collodion *uniodized* for more than a month or six weeks; the tendency to decomposition in the ether seems to be increased by the solution of the pyroxyline.

"Many operators take positives with a more highly iodized collodion intended for negatives, adding nitric acid to the bath, if the intensity is too great. This process is likely to yield pictures very clear and free from fogging, but is less sensitive than that just described, and often gives the shadows dark and sombre.

"*The Nitrate Bath.*—It is necessary to saturate this solution with iodide of silver, and to remove any free nitric acid which may be present. Therefore, having weighed out the following quantity of crystals of nitrate, &c., for the bath, viz.:—Nitrate of silver, crystallized *and dried*, but not fused, 25 grains; acetic acid (glacial), ½ minim; distilled water, 1 ounce; dissolve in about two parts of water. Then take iodide of potassium or ammonium, half a grain to each 100 grains of nitrate, dissolve in half a drachm of water, and add to the strong solution; a yellow deposit of iodide of silver first forms, but on stirring is completely redissolved. When the liquid is clear, drop in a solution of potash or carbonate of soda until a distinct turbidity, not removed by agitation, is produced (an excess does no harm); then dilute down the concentrated solution with the remaining portion of the water, stirring all the time, and filter out the milky deposit. If the liquid does not at first run clear, it will probably do so on passing it again through the same filter.

"Ammonia may also be used to neutralize free nitric acid, but it must be added very cautiously, or a quantity of oxide of silver will be dissolved, forming with the acetic acid, advised in the formula, acetate of silver *in excess*, which is injurious in a positive nitrate bath.

"After using any alkali or carbonate, the bath is left in a faintly alkaline condition, and unfit for use until the acetic acid has been added. If the *glacial* acetic acid be employed, it should be tested for impurities.

"Many, unaccustomed to chemical manipulations, may desire to avoid the trouble of saturating the bath with iodide of silver, and of removing the free nitric acid; in that case make it a little stronger than the formula, thirty grains to the ounce, omit the acetic acid, and remove the sensitive plate as soon as the layer of iodide of silver is formed.

"If the operator uses a collodion somewhat thicker than that recommended; or if large bluish patches of non-development occur in bringing out the image, the strength of the bath may be increased to thirty or thirty-five grains to the ounce.

"With regard to the length of time the bath will remain in working order no positive opinion can be given. If it begins to yield foggy pictures, try the effect of nitric acid, one minim to the half-pint of solution.

"The addition of alcohol to a positive nitrate bath is not recommended.

"*The Developing Fluids.*—Either of the three following formulæ may be used, according to the taste of the operator.

Formula No. 1.

Sulphate of Iron, recrystallized	12 to 20 grains.
Acetic Acid (glacial)	20 minims.
Alcohol	10 minims.
Water	1 ounce.

Formula No. 2.

Pyrogallic Acid	2 grains.
Nitric Acid	1 drop.
Water	1 ounce.

Formula No. 3.

Solution of Protonitrate of Iron	1 ounce.
Alcohol	20 minims.

"*Remarks upon these Formulæ.*—*Formula No.* 1 is the most simple, since the solution can be used as a bath, the same portion being employed many times succesively. If it acts too rapidly, lessen the proportion of sulphate of iron. An addition of nitric acid, half a minim to the ounce, makes the image whiter and more metallic; but if too much is used, the development proceeds irregularly, and spangles of silver are formed.

"The Alcohol and acetic acid render the development uniform by causing the solution of protosulphate to combine more readily with the film. The latter also has an effect in whitening the image and increasing its brightness.

"Solution of sulphate of iron becomes red on keeping, from a gradual formation of *persalt.* When it is too weak, add more of the protosulphate. The muddy deposit which settles to the bottom of the bath is metallic silver, reduced from the soluble nitrate upon the plates.

"Some operators add nitrate of potash to this developing solution (it must be pure nitre and free from chloride), so as to form a small portion of protonitrate of iron. It is said to improve the colour slightly. The proportions are ten grains of nitrate of potash to about fourteen or fifteen grains of protosulphate of iron.

"*Formula No.* 2.—In this formula, if the colour of the image is not sufficiently white, try the effects of increasing the amount of nitric acid slightly. On the other hand, if the development is imperfect in parts, and patches of a green colour are seen, use three grains of pyrogallic acid in place of two, with less nitric acid. Supposing this not to succeed, a few drops of nitrate of silver solution added to the pyrogallic, immediately before use, will augment the energy of development.

"*Formula No.* 3, or protonitrate of iron, does not require any addition of acid; but it will be advisable, in some cases, to add to it a few drops of nitrate of silver immediately before developing. This gives a bright metallic image, resembling that obtained by adding nitric acid to protosulphate of iron.

"The following are the processes commonly followed for preparing protonitrate of iron:—

"1st, *By the Action of Dilute Nitric Acid upon Sulphuret of Iron.*—Dilute an ounce of nitric acid with six ounces of water, and add to it about half an ounce of sulphuret of iron, previously broken into very small fragments. Set the vessel aside for several hours, in a place where the offensive and poisonous sulphuretted hydrogen gas may escape without doing injury. When all effervescence has ceased, pour off the green solution, add to it twenty grains of powdered chalk or whiting, and boil it in a flask for five minutes. Allow it to cool, and filter from it the black deposit, if any has formed. In this process the nitric acid, being in a diluted state and employed cold, does not act as an oxidising agent, but simply displaces sulphuretted hydrogen and forms protonitrate of iron. The chalk is added in order to neutralize a small portion of free nitric acid, which commonly remains after the action is complete. If a black deposit is noticed on boiling, it is sulphuret of iron produced by the excess of sulphuretted hydrogen, dissolved in the liquid, again reacting upon the protosalt of iron as the solution becomes neutral.

"2nd, *By Double Decomposition.*—This plan is somewhat less economical than the last, but probably superior to it in most other respects. Take of nitrate of baryta three hundred grains; powder and dissolve by the aid of heat in three ounces of water. Then throw in by degrees, with constant stirring, crystallized sulphate of iron powdered, 320 grains. Continue to stir for about five or ten minutes. Allow it to cool, and filter it from the white deposit, which is the insoluble sulphate of baryta.

"In place of nitrate of baryta, the nitrate of lead may be used (sulphate of lead being an insoluble salt), but the quantity required will be different. The atomic weights of nitrate of baryta and nitrate of lead are as 131 to 166; consequently 300 grains of the former is equivalent to 380 grains of the latter.

"*The Fixing Solution.*—Cyanide of potassium, two to twelve grains; common water, one ounce.

"Cyanide of potassium is usually preferred to hyposulphite of soda for fixing direct positives; it is less liable to injure the purity of the white colour. The per centage of carbonate of potash in commercial cyanide of potassium is so variable, that no exact directions can be given for the formula. It is best, however, to use it rather dilute—of such a strength that the plate is cleared gradually in from half a minute to a minute.

"The solution of cyanide of potassium decomposes slowly on keeping, but it will usually retain its solvent power for several weeks. In order to escape inconvenience from the pungent odour evolved by this salt, many employ a vertical bath to hold the solution; but in that case the plates must be carefully washed before fixing, as the iron salts hasten the decomposition of the cyanide.

"*The Whitening Solution.*—Bichloride of mercury, thirty grains; distilled water, one ounce.

"By a gentle application of heat, the corrosive sublimate dissolves and forms a solution as nearly as possible saturated at common temperatures. The addition of a portion of muriatic acid enables the water to take up a larger quantity of bichloride; but this concentrated solution, at the same time that it whitens more quickly than the other, is apt to act unequally upon different parts of the image.

"Before applying the bichloride, the image is to be fixed and the plate well washed. Either the protosulphate of iron or the pyrogallic acid with acetic may be used for the development; but the whitening process is more rapid and uniform in the latter case, the metallic particles being more finely divided.

"FORMULÆ FOR NEGATIVE SOLUTIONS.—*The Collodion.*—In making negative collodion the writer has succeeded best with pyroxyline prepared from paper (strips or squares of paper cut into small pieces, and dissolved in sulphuric acid and nitre, and washed in pyroxyline), which seem, from some unknown cause, to give more intensity than cotton. If the following solution is very fluid with three or four grains of pyroxyline to the ounce, as is often the case when the temperature of the nitro-sulphuric acid was high, it is useful to add a grain or so of a glutinous sample made from cotton, by which the requisite degree of viscidity is obtained. In this way, by combining the two, a collodion may be made which will yield excellent half-tones with any amount of intensity.

	Purified ether, sp. gr. ·720	5 drachms.
	„ alcohol, sp. gr. ·825	3 drachms.
	Soluble pyroxyline	3 to 6 grains.
	„ iodide of ammonium	3 to 4 grains.
Or,	Rectified ether, sp. gr. ·750	6 drachms.
	Alcohol, sp. gr. ·836	2 drachms.
	Soluble pyroxyline	3 to 5 grains.
	Iodide of potassium	4 to 5 grains.

"The film of iodide when formed in the bath should be tolerably dense, and more pyroxyline must be added to the collodion if it is blue and transparent; this increases the opacity better than an addition of alkaline iodide, the quantity of which should never exceed four, or at most five grains to the ounce.

"If the collodion is glutinous, and produces a wavy surface, with less than four grains of pyroxyline to the ounce, it is probable (unless the alcohol employed is inferior) that the soluble cotton was badly made. In that case, try Mr. Shadbolt's formula of adding of chloroform ten drops to each ounce of the fluid, and set it aside for twenty-four hours.

"In place of iodide of ammonium, in the first formula, a mixture of iodide of potassium and ammonium, or of potassium and cadmium, may be used; the former is especially recommended.

"If flakes of iodide of silver are seen loose upon the surface of the film, and falling away into the bath, the collodion is over-iodized, and it will be impossible to obtain a good picture.

"After the collodion has been employed to coat a number of plates, the relative proportions of alcohol and ether contained in it become changed, from the superior volatility of the latter fluid. Therefore, when it ceases to flow readily, and gives a more dense film than usual, thin it down by addition of a little rectified ether.

"Most operators adopt the plan of keeping on hand a stock of the plain collodion, and iodizing as required by the addition of alcoholic solution of iodide of potassium. The plain collodion, however, does not keep well beyond a certain length of time without a considerable development of the acid principle.

"In dissolving the pyroxyline, any fibrous or flocculent matter which resists the action of the ether must be allowed to subside, the clear portion being decanted for use. The iodide of potassium is to be finely powdered, and digested with the spirit for several days; if a saturated solution is required, it is better not to apply any heat. Both iodide of ammonium and iodide of cadmium should dissolve almost immediately, if the salts are pure.

"When this collodion becomes very highly coloured and insensitive, a part of the free iodine may be removed by a strip of pure zinc or silver foil; also the metallic powder obtained by reducing nitrate of silver with sulphate of iron acidified with nitric acid, answers well for the same purpose.

"Many operators, where sensitiveness is not an object, prefer working with an old collodion, thinking that it gives more intensity combined with half-tone. The latter part of this rule, however, is not universal, for if the quantity of iodide of silver in the film is small, the half-tones are best at the lemon-yellow stage of colouration. It is certain that some peculiar change takes place in collodion after iodizing, by which the intensity of the image is increased; and it is probable that this may be independent of colouration, for the author has observed that a grain or two of fresh iodide, added to a sample in excellent working order, immediately diminishes the intensity although the excess of free iodine remains the same.

"*The Nitrate Bath.*

Nitrate of silver, crystallized and dried . . .	30 grains.
Acetic acid (glacial)	$\frac{1}{4}$ minim.
Distilled water	1 ounce.

"This bath is first to be saturated with iodide and carbonate of silver, and the acetic acid is to be added subsequently.

"A negative nitrate bath, carefully shielded from the light, will remain in working order for many months. The proportion of nitrate of silver present becomes less after a time, but not to the extent that might *à priori* be imagined. About five grains of fresh nitrate per ounce will restore it to the original strength, even after a large number of plates have been coated.

"If a very brown sample of collodion is constantly employed, and the appearance of the negatives (misty and pale, greenish by transmitted light) leads at last to a suspicion of free nitric acid beginning to accumulate, add a single drop of ammonia to the half-pint of solution. The operator, however, should bear in mind that if the bath was neutralized when first prepared, it will take many ounces of brown collodion to liberate a perceptible quantity of free nitric acid in a twelve-ounce solution, and it is always better not to add an alkali, unless really required.

"*The Developing Solution.*—The quantity of acetic acid required in the following solution will vary with the strength of the acid and the temperature of the atmosphere. An excess enables the manipulator to cover the plate more easily before the action begins, but gives a bluish, inky hue to the image. In cold weather, use less acid and more free nitrate of silver in the developer:—

Pyrogallic acid	1 grain.
Acetic acid (glacial)	10 to 20 minims.
Alcohol	10 minims.
Distilled water	1 ounce.

"If the image cannot be rendered sufficiently black, two drops of the nitrate bath solution may be added to each drachm towards the end of the development.

"Also, the proportion of pyrogallic acid may, if required, be increased to two or even three grains to the ounce.

"If the solution be kept for some time after its first preparation, it is apt to become brown and discoloured. In order to avoid this, it has been recommended to make it about four times more concentrated than is necessary, and to dilute down with distilled water when required for use.

"*The Fixing Liquid.*—For remarks on the cyanide of potassium fixing bath see page 214.

	Cyanide of potassium	2 to 12 grains.
	Water	1 ounce.
Or,	Hyposulphite of soda	½ ounce.
	Water	1 ounce."

Defects and Remedies.—I have now to call the reader's attention to the failures he is pretty certain to meet with in his first attempts at photography, pointing out at the same time the usual causes, as far as they can be traced, and their remedies. In this study, however, as in all others, the operator must think for himself, and try to discover the causes of failure, as well as the required remedies, for it is not to be expected that they can all be foreseen in a treatise like the present. Among other annoyances, a number of small white or transparent spots in the negative will present themselves, caused by plunging the plate too rapidly in the nitrate bath, or dashing the developing solution too rapidly over the surface of the plate; in either case a number of minute air bubbles have been formed, which no after manipulation can remove or bring up to the same degree of intensity as the surrounding portions of the plate.

The plate blackens all over when the developing solution is used. This arises from many causes, viz., the plate may have been exposed accidentally to white light during some part of the process, or the camera or dark slide may admit light; this must be ascertained. Or it may be owing to over exposure; in this case the picture will be clean, but very feeble, and all the details may be made out. This may be very easily detected from another cause of blackening, owing to the bath or collodion being *alkaline* in a slight degree, and well known by the term "fogging." In this case we obtain an even black all over without the slightest trace of a picture. Should the blackening be owing to any of the causes named except the last, the cause at once suggests the remedy. If by the last named, it may be remedied by adding a drop or two of acetic acid to the nitrate of silver bath, or five or ten drops of tincture of iodine to the collodion. The latter must be done if the bath does not change slightly reddened litmus-paper into blue. Instead of adding the acetic acid to the bath, if you have time to expose it to the sun for some hours in a white glass bottle, it will be the safer way of bringing it back again. Should the blackening be of an irregular description, more on one part of the plate than another, it will probably arise from the rays of the sun shining nearly into the lens, or from some light reflected from the edge or inside tube of the lens, all which it will be necessary to look for in order to remedy the defect.

There are other means used to neutralize the acid bath. Mr. Hardwich recommends that the ammonia should be used in a very dilute state; but I think the use of ammonia in any shape very injurious. A writer in the Photographic Journal recommends a piece of rough white marble to be suspended in the bath by means of a piece of thread for a few days. Another recommends the addition of a few drops of dilute solution of caustic potash. That I also think objectionable. By far the best, simplest, and most successful plan, and one which I have used for some time, and which will succeed best in the hands of the amateur, as he cannot very well overdo it, is to scrape a small piece of pipe-clay or whiting into the bath, as much as will go on a sixpence to the pint; this effectually neutralizes the nitrate bath, which may be used immediately after being filtered.

Mr. Horne recommends a very good plan for restoring the bath when it becomes out of order through excess of iodide of silver in solution. He directs that a portion of pure distilled water should be added, say four ounces to a bath containing twenty or thirty ounces; this will precipitate the iodide, or a great part of it. The bath must then be filtered, and to it be added two drachms of nitrate of silver in crystals. The bath will then be in first-rate working order.

I shall again impress upon the amateur that nothing will neutralize an acid bath so well as a small piece of pipe-clay or whiting. In testing with litmus-paper after the addition of the whiting, &c., the test-paper will appear purple; but this will be owing to the carbonic acid, and will disappear if the paper be pressed between blotting-paper and dried at the fire. Chalk, being of the same nature as whiting (carbonate of lime), will answer quite as well.

Spots of black, printing white on the positive, more especially at the bottom of the latter. These are caused by dust, want of care in closing the shutter—viz., shutting it down with a bang—dirty developing glass, allowing drops of decomposed solution to fall on the plate from the bottom of the developing glass, or other piece of carelessness. The causes must be sought for by the amateur, and as they are always caused by careless manipulation, he must find out the remedy himself. There is an appearance often noticed in positives and negatives—in the one black, in the other white—similar to snow melting and freezing again into icicles, at the bottom of the picture; this is always caused by the top part of the plate-holder not being well wiped dry before the introduction of the plate; but, in some cases, the same appearance *almost*, but at the *top* part of the *positive*, takes place. This is generally caused by the plate being allowed to stand so long that the surplus solution of nitrate of silver drains off the surface of the plate, and accumulating at the end of the plate, which would be downwards at the time (the top in the positive), after being decomposed by contact with the surface of the plate-holder, reascends by capillary attraction. This is easily known by wave-like markings appearing at the *top* of the *positives*. These markings may be prevented by placing a slip of blotting-paper at the bottom part of the plate, on the back and lowest edge, when placing it in the dark slide; or merely placing a narrow strip in the bottom of the latter will do as well.

A black spot in one corner of the negative, about the size of a shilling, with several short lines from it, printing white in the positive. This is always produced by the contact of the finger with the excited plate, more especially if the finger has had on it the least trace of hyposulphite of soda.

Avoid the cause, and bear in mind that the fingers will always cause stains wherever they touch the surface of any photographically prepared plate or paper; and the fingers of some persons more than others, owing to the degree of moisture, holding chlorides, &c., in solution, they may possess.

Halo Light.—The positive has a sort of halo of light about the centre of the picture. The same appears in the negative, but reversed, *i.e.*, black; at the same time, there is a want of distinctness.

This is caused by reflected light in or from the lens. To ascertain the cause it will only be necessary to remove the ground glass, leaving the lens uncovered, place the focusing-cloth over the camera and look at the lens, when you will see an immense quantity of light reflected from its edges. This may be remedied by a very narrow diaphragm, or, what will do as well, a narrow streak of black varnish painted round the outside rim of the lens. It is a most curious fact, that some of our best lens makers, will not take any pains to remedy this defect, although it has been often pointed out to them; and, I may add, that I have never seen a lens without this defect more or less. The streak of black varnish, or the diaphragm, need not be wider than an eighth of an inch, just sufficient to cut off the light reflected from the edge of the lens. In double lenses used for portraiture there should always be a diaphragm between the front and back lens.

Irregular oily looking lines and spots resembling marble paper, or the appearance caused by attempting to cover a greasy surface with water. These are always to be traced to one of the following causes:—

Raising the plate out of the bath before it has been sufficiently long immersed (a minute at least); removing the plate too soon from the bath or before the ether has been washed away; re-dipping the plate after exposure (which should never be done), and proceeding to develop before the nitrate has been well drained off the surface; or reversing the plate from the position in which it was taken out of the bath, causing the silver solution to flow back again in lines, thus producing irregular action in the development.

Transparent spots and streaks are caused by impure ether, pouring the developing solution on the one spot, dirty glasses, more especially when the collodion is thin and the bath neutral. These more frequently occur when the glass is colder than the air in the room, the latter becomes condensed on the surface of the glass, which should not be covered until the moisture has evaporated again. When those spots are owing to some fault in the collodion, they may always be seen on the plate before exposure; and should any occur in an important part of the plate, it would be better not to use it. A reticulated appearance of the film is owing to impure alcohol or ether used in making the collodion, or to immersing the plate in the bath too quickly after being coated with collodion. One or two straight lines across the plate, transparent or nearly so, are caused by checking the plate in immersing it in the nitrate bath.

Irregularly-curved or circular black lines, separating a dark portion of the plate from another not so intense, are caused by not pouring on the developing solution evenly; for if you allow it to stop for a single instant on any one part of the plate, it will surely cause a line. There is a very nice arrangement for applying the developing solution, especially the protosulphate of iron. It is as follows:—A gutta-percha bath is made, part of which returns at right angles, or nearly so (Fig. 71), in which the plate A is shown resting against the back of the upper part C, C, C, on two small pieces or blocks of gutta-percha; the bottom part, B, B, holds the developing solution, and by turning it down (Fig. 72) the solution flows evenly over the surface. The same sort of bath will answer very well for the nitrate of silver bath. It should not be made at right angles, as the plate will rest more safely to drain, &c., when the bath is turned up again if it be made thus (Fig. 73). As the collodion dries round the neck of the bottle, it will be necessary to remove it carefully with the finger, previously to coating each plate, otherwise it will fall and spoil the film. When the collodion is too thick it will not flow evenly off the plate, and cause a cloudy irregular surface; it must then be thinned by adding ether *alone*, as the latter has evaporated in greater quantity than the alcohol.

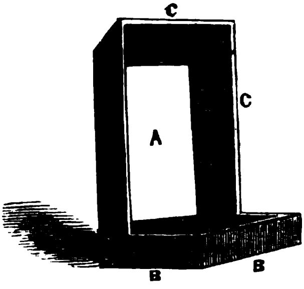

Fig. 71.

If, after a reasonable exposure in a good light, the negative is intensely black and white, with absence of half-tone, the bath is too acid, and must be neutralized by carefully adding a small quantity of ammonia-nitrate of silver solution, made by adding liquor ammonia to a solution of nitrate of silver, drop by drop, until the brown precipitate first formed be redissolved. The portions added to the nitrate bath should be very small indeed, and the bath tried after each addition. If so much be added as will cause fogging, then you must add a drop or two of acetic acid. All this must be done very carefully, or you will surely *spoil the bath*. The more acid the bath, the longer will be the exposure required; but amateurs will succeed better with a *slightly acid bath* than with a *perfectly neutral one*, the latter requiring much more care and delicate manipulation than the former; but the *neutral bath will always produce the finest photographs*. *Under-exposure* and *over-development* will produce effects almost similar to an acid bath.

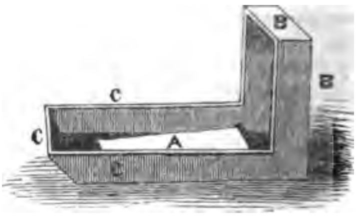

Fig. 72.

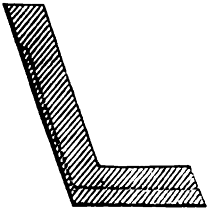

Fig. 73.

As collodion loses its sensitiveness when dry, there have been several methods thought of for preserving it moist for a considerable length of time; but I am inclined to give the preference to the plan proposed by Messrs. Spiller and Crookes, as I have taken a picture in that manner three days after the plate was made sensitive. They take advantage of the property possessed by certain "deliquescent" salts, which remain moist for any length of time when once melted; and many of them absorb moisture so eagerly from the air, that it cannot be easily driven off except by considerable heat. Nitrate of zinc and acetate of potash were the salts originally selected, but nitrate of magnesia has been substituted. Messrs. Spiller and Crookes' process is as follows:—

"The plate, coated with collodion in the usual manner, is to be rendered sensitive in a thirty-grain nitrate of silver bath, in which it should remain rather longer than is generally considered necessary (about five minutes); it must then be slightly drained and immersed in a second bath, consisting of

Nitrate of magnesia	4 ounces.
Nitrate of silver	12 grains.
Glacial acetic acid	1 drachm.
Water	12 ounces.

And there left for about five minutes, then removed and placed in a vertical position on blotting-paper, until all the surface-moisture has drained off and been absorbed. This generally takes about half an hour, and they may then be packed away in any convenient box until required for use.

"Not only is the sensitiveness unimpaired by this treatment, but we think, on the contrary, that it is slightly increased; instantaneous negatives have been taken on plates which had been prepared some days previously. We are not yet in a position to give the length of time that may elapse between the preparation of the plate and development of the picture; such experiments necessarily require a more lengthened period than we have at present been able to give, but as long as they have yet been kept (upwards of three weeks) there has been no appearance of deterioration.

"Before the development, we find it advisable to moisten the collodion film by immersion in the silver bath for about half a minute, as otherwise the pyrogallic acid or iron solution would not flow evenly over the plate. The fixing, &c., is of course conducted as usual.

"It will be as well to draw attention to a few points which, although not absolutely essential, may possibly be found useful in practice. The glass plates should be cleaned with more care than is necessary when they are to be used immediately; we have found strong nitric acid applied with a tooth-brush most convenient. With regard to the collodion, we have tried many different samples, and with tolerably uniform success. The greater number of our experiments have been made with a tolerably thick collodion, the alcohol and ether of which were in the proportion of 1 : 2, made sensitive with four grains of iodide, and half a grain of bromide of ammonium to the fluid ounce. We have also employed a collodion containing iodide and bromide of cadmium with good success.

"Of the thirty-grain silver solution for exciting the plate, we have only to recommend the use of acetic instead of nitric acid, to give the bath that faintly acid reaction which is by some operators considered desirable.

"There are one or two circumstances to be attended to in the preparation of the magnesia bath. Commercial fused nitrate of magnesia is very liable to contain chlorine, and also to have an alkaline reaction on account of the fusion being carried too far. Of course the quantities of acetic acid and nitrate of silver given in the formula for the bath, are on the supposition that the nitrate of magnesia is pure; if this be not the case, it should be rendered perfectly neutral with acetic acid, the chlorine exactly precipitated with nitrate of silver, and then the proper amounts of acid and silver added. However, if the impurities are very considerable, it will be safer to reject the salt at once. This bath will keep in good order for a long time; the only point to be attended to is to drain the plates slightly after coming from the silver bath, and, if necessary, to remove the liquid from the back with blotting-paper, so as to introduce as little silver as possible into the nitrate of magnesia. A solution of one grain of silver to the ounce is quite sufficient to keep the plates sensitive; and when the strength rises, as it will in time, to above a certain limit, the slight evaporation that always takes place will render the silver solution sufficiently strong to dissolve off the iodide in small holes. If this occur, the bath can be restored by nearly, but not quite, precipitating the silver with a solution of chloride of magnesium, and then filtering.

"One of the most important things to be attended to is, the necessity of preserving the plates where they are perfectly free from any light. It will be evident to all, that anything short of absolute darkness, when the sensitive surface is exposed to its action day after day, and perhaps week after week, must be fatal to its subsequent cleanliness. The necessity for protecting the plates from any deleterious gases—ammonia, for instance—is too obvious to require comment."

As it is not very easy to obtain the nitrate of magnesia pure enough for photographic purposes, the following observations by Mr. Hardwich may be interesting here:—

"*Nitrate of Magnesia.*—Nitrate of magnesia may be prepared by dissolving magnesia or its carbonate in dilute nitric acid. It crystallizes with difficulty in rhomboidal prisms, which are deliquescent and soluble in an equal weight of water. When intensely heated, it loses both water and acid, and magnesia remains.

"Commercial nitrate of magnesia usually contains chloride of magnesium, and if it has been strongly fused, nitrite of magnesia and oxide of magnesium; it will be better, therefore, to prepare it purposely for photography.

"A solution of nitrate of magnesia, of about the strength recommended by Mr. Spiller for preserving the sensitiveness of collodion plates, may easily be obtained as follows:—Take five fluid ounces of a colourless sample of nitric acid of the common strength, sold at about tenpence per pound (specific gravity, 1·36 to 1·4), and dilute it with seven ounces of water; then weigh out carbonate of magnesia four ounces, and add it by degrees until all effervescence has ceased, and an excess of magnesia remains, rendering the liquid milky. Next add the nitrate of silver recommended in the formulæ, viz., twelve grains, which, however, may conveniently be increased to half a drachm; agitate well until a piece of reddened litmus-paper changes to blue on immersion it in, showing that the bath is alkaline, and then filter from the white deposit and add of glacial acetic acid one drachm, as recommended.

"In this process, the carbonate of magnesia first neutralises the nitric acid, converting it into nitrate of magnesia; the nitrate of silver decomposes any soluble chloride which may be present, precipitating it in the form of chloride of silver, and also reacts upon the excess of carbonate of magnesia, producing carbonate of silver, which renders the bath alkaline; lastly, the acetic acid removes the alkalinity, leaving in the liquid a trace of acetate of silver, thus giving absolute security against the existence of any free nitric acid, which would destroy the sensitiveness of the preserved plates.

"The solution when completed will usually contain a small quantity of soluble sulphate (evidenced by chloride of barium); the precipitated carbonate of magnesia being rarely washed sufficiently to free it from all traces of sulphate of soda and chloride of magnesium or sodium."

More recently Mr. Shadbolt has proposed to improve the process of Messrs. Spiller and Crookes by using honey instead of the nitrate of magnesia. Although honey cannot be classed with the deliquescent salts, in common with other uncrystallisable sugars, it has the property of remaining moist for a considerable time.

Mr. Shadbolt's process is as follows:—"Having prepared and excited the collodion in the usual manner, on its removal from the bath of nitrate of silver it is to be drained pretty closely for about half a minute, and then immersed in a second bath, consisting of distilled water twenty to thirty ounces to one ounce of the exciting bath (the exact quantity is not of great moment), and allowed to remain in the latter mixture until the liquid flows evenly on lifting the plate up, which will happen in about from two to three minutes after immersion. The object of this proceeding is to wash away all but a slight trace of free nitrate of silver, as one of the causes of deterioration of the plate is the crystallization of this salt on the surface of the collodion. This distilled water bath should be in a vertical vessel, similar to that used for exciting, and the same bath, if freed from impurities as they accumulate, will do for an indefinite time. To distinguish it, I shall term it the washing bath.

"The plate may be removed from this bath as soon as the liquid flows freely, and again drained closely, when a portion of the preservative syrup is to be poured on and and off once or twice, being careful to avoid bubbles, or any minute particles of matter being left on the plate; which is then to be placed upright upon clean blotting-paper with the collodion-side towards the wall to drain. In about ten minutes' time, the lower edge of the plate where the syrup has been collected, may be touched lightly with fresh blotting-paper to remove the superfluity, and then placed in the dark frame, or stored away in a box for future use. It is not necessary to perform this operation until convenient.

"The preservative syrup is thus made:—Take of pure honey and distilled water equal parts by measure, mix thoroughly and filter. In my former directions a sixth part of the volume of alcohol was included; but further experience leads me to consider this unnecessary, if not detrimental.

"If thoroughly excluded from the action of light, plates thus prepared will keep good for a very long time. The sensibility is certainly less than when fresh plates are used, and I judge that the exposure required is about double the time, for the same collodion, if used immediately after its removal from the nitrate bath; but I cannot detect any further diminution for the first twenty-four hours, and I have taken a picture no less than three weeks after excitation, but with at least four times the exposure required for a fresh plate. I do not, however, recommend the plates to be kept longer than is really necessary, as the chances of change from very little actinic force are certainly great.

"The plates may be developed even as long as twelve hours after exposure. This part of the process is conducted as follows:—

"The plate is to be again immersed in the washing bath and left from one to ten minutes to soak, occasionally lifting it up and down to facilitate the removal of the superfluous syrup, and thoroughly to soften what remains upon the plate. The longer the latter has been kept, the longer it should be allowed to soak.

"When taken out, a sufficient quantity of the developing solution is to be poured over the plate in the ordinary way, and, provided the paper has been properly soaked in the washing bath, there is no greater difficulty experienced in getting it to flow over than when a fresh plate is used. The image should appear very slowly, and when all the details are out but very faintly; the developing solution is to be returned into the measure (taking especial care not to allow the small portion remaining on the plate to run in lines), a feat readily performed if done quickly, and the plate instantly restored to a horizontal position. A small quantity of the exciting bath (a thirty-grain solution of nitrate of silver), from an eighth to a sixth of the volume of the solution that was poured from the plate into the measure, together with a like proportion of the preservative syrup, should now be added to the liquid in the measure and well mixed up; this is to be poured on the plate and kept moving until the picture is sufficiently intense, which can be carried to any degree if the exposure has been proportionately prolonged. So intense can the high lights be made, that a whole day's exposure to direct sunshine will not print through them. Of course I only mention this to show what can be effected—not what is desirable.

"The developing solution I adopt consists of one grain to the ounce of water solution of pyrogallic acid, one-fourth of the menstruum being the ordinary acetic acid of the druggists, or, if glacial acetic acid is used, one-twelfth part is sufficient."

There have been other suggestions for keeping the collodion plate moist, and therefore sensitive; such as keeping the excited film between two glasses, &c. I fear that they are all of no use; amongst the number, the following promises to be the most successful, but I must add that I have never tried it:—

Captain Caron, of the French artillery, has addressed to the Société d' Encouragement the description of the following process of photography upon dry collodion:—

"The manipulations in the employment of dry collodion are the same as for the moist; the difference lies in the substitution of chlorides for the iodides, which, without exception, lose their sensibility by drying. The chloride of silver is as sensitive in the dry state as when moist; and although its sensibility is not equal to that of moist iodized collodion, it nevertheless remains superior to that of collodion preserved by sugar, honey, mucilage, or salts, which besides have the inconvenience of becoming soiled by dust. The following are M. Caron's preparations:—

"Take of pure collodion three and a-half fluid ounces, add ten, twelve, or fifteen drops of chloride of iodine—as an average, twelve; spread on the glass; plunge in a bath of fused nitrate of silver (forty grains to the ounce), wash with common water; let the glass drain, and dry it. From the dampness of the weather, M. Caron has always dried rapidly at the fire; he is not sure whether this is indispensable.

"Take the impression in the camera or behind a negative. Re-dip the plate in the bath of nitrate of silver for several seconds; develop the image with pyrogallic acid, as for moist collodion; pyrogallic acid fifteen and a-half grains, water ten ounces, acetic acid two and a-half drachms; with the following bath, pyrogallic acid fifteen and a-half grains, water one and a-half pint (imperial), acetic acid two and a-half drachms, the image comes out more slowly, but better. Fix with cyanide of potassium of one five-thousandth (' au cinq millième '); wash, dry.

"The following fact will give an idea of the duration of the exposure:—On a dull day, to print through a negative on collodion, required an exposure of two to three seconds. So long as the image does not acquire a red colour with pyrogallic acid, the exposure has not been sufficient.

"This process is evidently exceedingly simple; and if it gives good impressions, it will be generally adopted. M. Caron says nothing respecting the quality of those that he has obtained; it is true, however, that we are in the midst of winter.

"MM. Duboscq and Tavernier have tried this process, and their results promise much. The collodion applied in this way has all the advantages of albumen, and the drying by the fire appears of great utility."

The process published by Mr. Shadbolt, which certainly possesses great advantages, is very ably followed up by Mr. Mansell, of Guernsey, who published a modification or improvement on Mr. Shadbolt's process. It is nearly as follows:—

After paying some merited compliments to Mr. Shadbolt for his valuable invention, Mr. Mansell adds—"The plate having been carefully cleaned and iodized as usual, the subsequent manipulation resolves itself into three heads.

"First. To reduce the amount of free nitrate of silver on the plate to nearly the minimum necessary for its sensitiveness in the camera.

"Having drained the plate, immerse it in a vertical bath of distilled water for one or two minutes; take it out, and drain it by resting one edge on blotting-paper. Another method is to pour on the plate, very gently, and not on one spot, as much distilled water as it will carry, leaving it on for two minutes. I prefer the washing-bath; but the second method may be useful on occasion.

"*Remarks.*—The addition of nitrate of silver to the washing-bath is superfluous; the capillarity of the villous surface of the iodized film retains as much as is necessary. The bath of course soon acquires nitrate of silver from the plates; but this is no injury till it becomes excessive. When the amount exceeds one grain per ounce, the bath must be diluted.

"Second. To preserve the surface of the plate moist, and the free nitrate of silver on it from crystallizing, by means of a hygrometric coating of syrup.

"Give the washed plate two doses of syrup, leaving each on for about two minutes, with waving. I use syrup which has done duty as the second dose of one plate, for the first dose of the next plate, always finishing with fresh syrup. Oscilate the plate from angle to angle, resting on blotting-paper, to obtain a perfectly mirrored surface, and store away for use. The plates will keep for a month or six weeks.

"*Remarks.*—The syrup is made by taking, half and half, pure honey and distilled water, and filtering; in fact, it ought to be as dense as can pass through ordinary white filtering-paper. The greatest care should be taken to avoid the reduction of any portion of the free nitrate of silver in long-kept plates, by having the hygrometric film as free from it as possible.

"Third. To remove the syrup perfectly from the plate before developing.

"On this the perfection of the result mainly depends. The syrup, after it has been on the plate a short time, consists of two layers; an outer one, which remains soft and hygrometric for a long time, and is soluble in cold water, and an inner film, a compound of syrup and nitrate of silver, which is insoluble in cold water. This is easily proved by washing the plate in a vertical glass bath, where this layer is seen separating in bran-like scales, the water mechanically removing it. These scales may also be collected on a filter and examined. This inner layer (with a mean temperature of 46° Fah., and a mean degree of humidity of ·836), after about 150 hours, becomes adherent to the collodion—at first round the margins of the plate, and then to the whole surface, covering it as with a varnish, which no amount of washing in cold water will remove. This indurated syrup is soluble in hot water; but it is far more effectually and safely got rid of by steaming. On removing the plate from the dark slide, immerse it in the washing-bath for five minutes, to remove the outer syrup; drain it, then hold it, collodion downwards, over the steam of boiling water, poured in a pan, for about ten minutes (the water is to be renewed if the steam does not rise freely), taking care to keep the plate four or five inches from the surface of the water; the indurated syrup will be seen gradually to dissolve, and, by inclining the plate, may be run off at any angle you choose. In the process of steaming, if any part of the surface is disposed to dry, as will sometimes be the case, where the coating of syrup happens to be thinner than elsewhere, it must be kept wet by causing the fluid on the plate to run over it. Allow the plate to drain, then remove the remaining syrup by gently pouring distilled water over it once or twice. Drain the plate, and pour on pyrogallic acid (no image whatever appears under this); after a minute or two, when the iodized film has been well impregnated, pour off the pyro into a glass containing about an eighth of its volume of a thirty-grain nitrate of silver solution, and immediately pour it over the plate. The image rapidly comes out, and may be developed as usual to any extent.

"*Remarks.*—The first washing-off of the outer layer of syrup may be effected by pouring one or two waters on the plate, leaving them on for a few minutes. I prefer the washing-bath, and only mention this as a makeshift for travellers, who may thus avoid the necessity of carrying one. The development is so even, that on a 9 × 7 plate it is almost impossible to say where it commences; the uniform anastasis of the picture is one of the most beautiful experiments that can be witnessed—it rises up like an exhalation, and its perfection is exquisite. The negative high lights are as transparent as glass, and the half-tones and blacks all that can be desired. The steamed and washed plate, before development, consists of a film of iodide of silver, nearly pure, in a state of actinic tension, the free nitrate of silver having been almost entirely removed; indeed, by repeating the steaming and washing, this can be done so perfectly that the plate may be exposed to diffused daylight without injury. This is a remarkable experiment, which throws so much light on the theory of this truly wonderful art, that it will amply repay any one who has leisure and talent to follow it up. The negatives obtained from plates that have thus been deprived of their original free nitrate of silver, are equal in every respect to others that have not been so treated. Among other advantages, steaming the plates cleanses them so perfectly, and gives us such complete mastery over this method, that I now always use it, whether kept a long or a short time; the trouble is nothing, the result certain."

Mr. Mayall's Dry Collodion Process.—As the subject of preserving collodion plates for a long time without destroying their sensitiveness is one of vital importance, I cannot refrain from giving Mr. Mayall's process for using a dry collodion; and I may add that the same gentleman, at a considerable sacrifice of time and money, gave one of the most instructive lectures on the albuminized process on glass ever brought before the London Photographic Society. I have already given the substance of this lecture, and shall now give his method for using dry collodion, as copied from the pages of the London Photographic Journal:—

"The object of this paper," he says, "is to explain a process by which collodion can be used dry. It may be well, before describing the mere process, if we endeavour to comprehend somewhat of the chemical action which is necessary to the production of a good collodion, and to explain the law of substitution, upon which the reactions of this highly complex organic compound may be said to depend.

"It is well known to chemists that there are a number of organic substances, which, when treated with chlorine gas, take up a number of measures of that gas, equal to the number of measures of hydrogen that are taken from it by another portion of the chlorine. Gay Lussac was the first to observe this phenomenon, and Dumas afterwards remarked the same change in oil of turpentine, and founded upon it his 'theory of substitution.'

"Example:—Acetic acid, $C_4H_4O_4$, is converted by the action of chlorine into chloracetic acid, $C_4\ HCl_3\ O_4$, without altering the form or appearance of the original acid.

"This latter product forms with oxide of silver a soluble salt, without any precipitation of chloride of silver; whereas chlorine, in all the inorganic compounds of which it forms the electro-negative element, yields with silver solutions a precipitate of chloride of silver.

"Again, ether may be taken as oxide of ethyl, C_4H_5O, ethylene being the primary nucleus, $C_4H_4 + HO$; by the successive action of chlorine it may be converted as follows:—

Oxide of ethyl	$C_4 H_5 O$
By action of chlorine becomes	$C_4 H_4 Cl O$
	$C_4 H_3 Cl_2 O$
	$C_4 Cl_5 O$

"It will be observed that the chlorine displaces an atom of hydrogen, and this action continues until hydrogen vanishes from the series.

"Now, although chlorine was the first electro-negative element that was observed to have this property of substitution, more recent investigation has shown that iodine, bromine, and even fluorine and some of the metals, have the property also, and form with ether:—

Oxide of ethyl	$C_4 H_5 O$
Iodide of ethyl	$C_4 H_5 I$
Bromide of ethyl	$C_4 H_5 Br.$
Chloride of ethyl	$C_4 H_5 Cl.$
Zincethyl	$C_4 H_5 Zn.$

And the metal ethyls again form iodides, bromides, &c.

"Now these ethyls on a first glance should be analogous to the true iodides, chlorides, bromides, and should immediately yield precipitates with the usual tests employed for their detection; but they do no such thing; they are completely masked, and do not exhibit any of their usual characteristics. If, with Berzelius, in his *Binary Theory*, we regard them as compounds of chlorine, iodine, and the radical ethyl $C^4 H_5$, they do not precipitate silver solutions. The chlorine, iodine, bromine, exist in their constitution in a totally different manner.

Similarly, marsh gas	$C_2 H_4$
produces Chloroform	$C_2 H Cl_3$
Bromoform	$C_2 H Br_3$
Iodoform	$C_2 H I_3$

"Laurent and Gerhardt, in the French school, have greatly expanded this subject, and, in the opinion of chemists, have even gone too far to accord with well-established views in chemistry. Much remains for the experimentalist before the true limits of substitution can be properly defined.

"One thing, however, is established without fear of controversy; that is, that oxide of ethyl when brought into contact with chlorine, first loses its hydrogen, and is transformed into a chlorethyl, and eventually every atom of its hydrogen is abstracted.

"Iodine produces a similar effect, until at last the iodide of ethyl has completely replaced the original ether, and has produced that decomposition which it is the province of the light to effect. Hence a collodion that has undergone this change is no longer, or only feebly, sensitive to the electro-negative ray of light, and this will account for the deterioration of excited collodion.

"Now, as every excited collodion becomes deteriorated by keeping, the question has strongly impressed me—Is it possible to impregnate the ether with any substance rich in hydrogen that would repair the waste going on in the excited collodion? And, after trying various substances, I have found four that do actually repair, or rather that give off their hydrogen first, and so keep the ether intact. These are—

Benzine . . .	$C_{14} H_5 O_2$
Naphthaline . .	$C_{20} H_8$
Hellenin . . .	$C_{15} H_8$
Terpenole . .	$C_{28} H_{17} O$

"Very small quantities of these substances added to the ether prevent it running into iodides, bromides, and chlorides of the ethyls, still leaving in the collodion sufficient of electro-positive elements to enable the light to push the iodide of silver out of its feeble combination.

"What Liebig calls the eremecausis of organic bodies—that is, the slow decomposition by the absorption of oxygen—is one of the leading characteristics of highly complex organic forms rich in hydrogen, analogous to putrefaction of nitrogenized substances. In the instances above quoted there are two affinities in action:—first, the affinity of nitrogen for hydrogen, and of carbon for oxygen, and both facilitate the disruption of the elements of the complex organic form; decay and utter annihilation of organism takes place; the elements are again restored to the inorganic world. Those who wish to pursue the inquiry as a purely chemical investigation, I refer to Liebig's 'Vegetable Physiology.'

"The chemistry of this process is somewhat obscure. However, some of our ablest photographic chemists are now investigating it, and no doubt from their labours much may be expected.

"The usual plain collodion is excited with—

"No. 1.—3 grains of iodide of cadmium.
1 grain of chloride of zinc.
1 ounce of collodion.
½ ounce of alcohol.

"Dissolve the chemicals in the alcohol, and then mix with the collodion.

Or, No. 2.—3 grains of iodide of zinc.
1 grain bromide of cadmium.
Or, No. 3.—2 grains iodide of cadmium.
1 grain bromide of cadmium.
$\frac{1}{60}$ grain bromide of iron.
$\frac{1}{20}$ grain bromide of calcium.

"In the last it will be necessary to dissolve one grain of bromide of iron in one drachm of alcohol, and use one fluid grain of the solution. Similarly three grains of bromide of calcium must be dissolved in one drachm of alcohol, and one fluid grain used.

"The excited collodion will require to stand a few days to settle completely. Decant into a dry bottle, to avoid sediment. Spread as usual.

"*Bath*—which for distinction sake we will call albuminate of silver:—

16 ounces distilled water.
1 ounce albumen.
1½ ounce nitrate of silver (neutral).
1½ ounce glacial acetic acid.
2 grains iodide of potassium.

"The albumen and water must be well mixed first, then the glacial acetic acid added; shake up, and let stand three hours; then the nitrate of silver in crystals, shake and filter, stand twenty-four hours; then add the iodide of potassium, filter again, ready for use. Coat the plate, as usual, with collodion, and use the albuminate of silver bath as an ordinary silver bath; wash in another bath of distilled water five minutes, then wash the back of the plate with common water, the front with distilled; set the plate aside to dry in a vertical position, in a place free from dust. It will keep three weeks. Expose in the camera as usual, from two minutes to ten, according to the light, diaphragm, &c. Pass into the silvering bath again three minutes. Develop with—

6 to 8 grains protosulphate of iron.
1 ounce distilled water.
1 drachm glacial acetic acid.

Wash, and fix with—

1 cyanide of potassium.
20 water.

"It is about as quick as albumen in the camera. The albuminate of silver bath must on no account be exposed to daylight, nor the developing solution. Potassium and ammonium salts will do to excite the collodion; but it will not keep so long as with the metallic iodides.

Tests of the Strength of Acids.—One of the great causes of failure, to which the best photographers are liable, is to be found in the adulteration and impurity of the chemicals used. To this question Mr. Hardwich directed much of his attention, and the following are some of the tests and remedies his experiments suggested to him:—

"*Nitro-Sulphuric Acid.*—Plan for making nitro-sulphuric acid, the specific gravity of the two acids not having been previously determined:—Take a strong sampie of nitric acid (the yellow nitrous acid, so called, succeeds very well), and mix it with oil of vitriol as follows:—

Sulphuric acid . . .	10 fluid drachms.
Nitric acid	10 ,,

"Now immerse a thermometer, an indispensable article, and note the temperature. If the oil of vitriol is good, it should be about 130°. If it sinks below 120°, place the mixture in a capsule (a teacup will answer the purpose), and float upon boiling water for a few minutes.

"Having done this, a preliminary experiment with a small tuft of cotton wool will speedily indicate the actual strength of the nitro-sulphuric acid. Stir the tuft in the mixture for five minutes. Remove it with a glass rod, and wash with water for ten minutes until no acid taste can be perceived. If the wool becomes matted, and gelatinizes slightly on its first immersion in the acid; or if, in the subsequent washing, the fibres appear to adhere and to be disintegrated by the action of the water, the nitro-sulphuric acid is too weak. In that case, add to the acid mixture oil of vitriol three drachms. If the cotton was actually dissolved in the first trial, an addition of half a fluid ounce of oil of vitriol may be required.

"Supposing the cotton not to be gelatinized and to wash well, then wring it out very dry, pull out the fibres, and treat it in a test-tube with rectified ether, to which a few drops of alcohol have been added. If it is insoluble, dry it by a gentle heat and apply a flame. A brisk explosion indicates that the nitro-sulphuric acid employed is too strong. In that case, add to the twenty drachms of mixed acids, water one drachm, or even one drachm and a half, if the compound was very highly explosive.

"There is a third condition, somewhat different from either of the above, which is puzzling to a beginner. It is this:—The fibres of the cotton mat together very slightly or not at all on immersion, and the washing proceeds tolerably well; the compound formed is scarcely explosive, and dissolves imperfectly in ether, leaving little nodules or hard lumps of unaltered cotton. The ethereal solution yields, on evaporation, a film which is opaque instead of transparent. In this case, the acid mixture is slightly too weak, or the temperature is too low, being probably about 90° instead of 120° to 130°. When the acid mixture has been brought to the proper strength by a few preliminary trials, proceed according to the directions given a few pages in advance.

"*Preparation of Nitro-sulphuric Acid.*—The process by oil of vitriol and nitre is recommended, in preference to the other, to the amateur who is unable to obtain nitric acid of convenient strength. The common oil of vitriol sold in the shops is often very good for photographic purposes; nevertheless it is best, if possible, to take the specific gravity. At a temperature of 58° to 60°, specific gravity 1·833 is about the usual strength, and if it falls below this, it will be better to reject it.

"The nitre should be the purest sample which can be obtained. Commercial nitre often contains a large quantity of chloride of potassium, detected on dissolving the nitre in distilled water, and adding a drop or two of solution of nitrate of silver. If a milkiness and subsequent curdy deposit is formed, chlorides are present.

"These chlorides are injurious; after the oil of vitriol is added, they destroy a portion of nitric acid by converting it into brown fumes of peroxide of nitrogen, which alters the strength of the solution.

"Therefore, if pure nitrate of potash, free from chlorides, can be obtained, the slight additional expense is not worth being taken into account; but if not, the finest crystals of commercial nitrate may be picked out, and will probably answer the purpose.

"Nitrate of potash is an anhydrous salt—it contains simply nitric acid and potash, without any water of crystallization; still, in many cases, a little water is retained mechanically between the interstices of the crystals, and therefore it is always better to dry it before use. This may be done by laying it in a state of fine powder upon blotting-paper, close to a fire, or upon a heated metallic plate.

"Whether previously dried or not, the sample must be reduced to a fine powder before adding the oil of vitriol; otherwise portions of the salt escape decomposition.

"Supposing these preliminaries to have been properly observed, weigh out pure nitre, powdered and dried, 600 grains. This quantity is equivalent to one and a quarter ounce troy or apothecaries' weight, and to one and a quarter ounce avoirdupois weight + 64 grains. Place this in a tea-cup or any other convenient vessel, and pour upon it water one fluid drachm and a half mixed, with oil of vitriol twelve fluid drachms. Stir well with a glass rod for two or three minutes, until all effervescence has ceased, and an even pasty mixture, free from lumps, is obtained.

"During the whole process, abundance of dense fumes of nitric acid will be given off, which must be allowed to escape up the flue or into the open air.

"The above formula will invariably succeed with a good sample of oil of vitriol and pure nitre. When tried, however, with commercial nitre, it failed in the writer's hands, the cotton being gelatinized and dissolved. Therefore, in a second experiment, the addition of water was omitted, and the result proved satisfactory."

Mr. Hadow recommends the following for employment with commercial nitre :—

Nitre, powdered and dried . .	510 grains.
Oil of vitriol	15½ drachms.
Water	1½ drachm.

"Observe that the quantity of oil of vitriol in this formula is increased, to allow of the water being retained. The resulting mixture is very fluid and transparent, and the manipulation easy. The writer has seen this formula tried twice, with samples of common nitre purchased at an oil-shop. In the first the product was highly satisfactory, but in the second not quite so good, being only partially soluble and giving an opalescent film. In this case, probably, a better result would have been obtained by halving the quantity of water directed.

"*Washing and Drying the Pyroxyline.*—The mixture of sulphuric acid and nitre requires to be used immediately after its preparation, as it solidifies into a stiff mass on cooling; but the mixed acids may be kept for any length of time in a stoppered bottle.

"The fibres of the cotton should be well pulled out, and small tufts introduced singly, stirring with a glass rod in order to keep up a constant interchange of particles of acid. The paper is cut into small squares or strips, and treated in the same way.

"The quantity of either must not be too great, or some portions will be imperfectly acted upon; about twenty grains to each fluid ounce of the mixture will be sufficient.

"Time of immersion varies from ten minutes with cotton to twenty minutes, or even half an hour, with the paper. When an unusually large proportion of sulphuric acid is used, as in the formula given for the commercial nitre, the cotton should be removed at the expiration of six or seven minutes, as there is a tendency to partial solution of the pyroxyline in the acid mixture under those circumstances.

"After the action is complete, the nitro-sulphuric acid is left weaker than before, from addition of various atoms of water necessarily formed during the change. Hence, if the same portion be used more than once, an addition of sulphuric acid will be required.

"In removing the pyroxyline from the nitro-sulphuric acid, press out as much of the liquid as possible, and wash it rapidly in a large quantity of cold water, using a glass rod in order to preserve the fingers from injury. If it were simply thrown into a small quantity of water and allowed to remain, the rise in temperature and weakening of the acid mixture might do mischief.

"The washing should be continued for at least a quarter of an hour, or longer in the case of paper, as it is most essential to get rid of every trace of the acid. When the nitre plan has been adopted, a portion of the bisulphate of potash formed adheres very tightly to the fibres, and if not carefully washed out, an opalescent appearance is seen in the collodion, resulting from the insolubility of this salt in the ethereal mixture.

"If no acid taste can be perceived, and a piece of blue litmus-paper remains in contact with the fibres for five minutes without changing in colour, the product is thoroughly washed. Nevertheless, if time can be spared, it is a safe plan to place the pyroxyline in warm water, and allow it to soak for several hours.

"Lastly, wring it out in a cloth, pull out the fibres, and dry by a gentle heat, always bearing in mind that the compound is more or less explosive, and therefore must not be brought too near to the fire. After drying, it may be kept for any length of time in a stoppered bottle. It has been stated, on good authority, that pyroxyline is in some cases liable to a spontaneous decomposition, attended with evolution of red fumes of peroxide of nitrogen. This, however, must be rare, as the writer has not often met with it in the course of his experience.

"RECAPITULATION.—*The Acid Mixture too strong.*—The appearance of the cotton is not much altered on its first immersion in the mixture. It washes well, without any disintegration. On drying, it is found to be strong in texture, and produces a peculiar crackling sensation between the fingers, like starch. It explodes on the application of flame, without leaving any ash; it is insoluble in the mixture of ether and alcohol, but dissolves if treated with acetic ether.

"*The Acid Mixture of the proper strength.*—No agglutination of the fibres of the cotton on immersion, and the product washes well; soluble in the ethereal mixture, and yields a transparent film on evaporation.

"*The Acid Mixture too weak.*—The fibres of the cotton agglutinate, and the pyroxyline is washed with difficulty. On drying, the texture is found to be short and rotten. It does not explode on being heated, but either burns quietly with a flame, leaving behind a black ash (in which case, probably, it consists simply of unaltered cotton), or is only slightly combustible, and certainly not explosive. Treated with the ethereal mixture, it dissolves only partially, leaving behind lumps of unchanged cotton. The solution does not form an even transparent layer on evaporation, but becomes opaque and cloudy as it dries. This opacity, however, may be seen to a small extent with any sample of pyroxyline, if the solvents contain too much water.

"By studying these characters, and at the same time bearing in mind that a drachm and a half of water in the quantities of acid given for the formulæ will suffice to cause the difference, it is hoped that the operator will overcome all difficulties.

"*Purification of Collodion Solvents.*—The purity of the ether employed is a matter of more importance in the manufacture of a good collodion than that of any other ingredient. This point must be attended to in order to secure a good result.

"There are three kinds of ether sold by manufacturing chemists:—First, ordinary rectified sulphuric ether, as it comes from the distilleries, containing a certain per centage of alcohol, and also of water; if it is good, the specific gravity is about ·750. Second, the washed ether, which is the same agitated with an equal bulk of water, in order to remove alcohol. By this proceeding the specific gravity of the fluid is reduced considerably. Third, ether both washed and re-rectified, so as to contain neither alcohol nor water; in this case the specific gravity should not be higher than ·720.

"The first of these commercial varieties is the one usually employed by photographers, since it is sold at a lower price than the others; sometimes it is exceedingly pure and good, and is then to be preferred to the washed ether; but often this is not the case.

"Some of the qualities which render ether unfit for photographic purposes, are as follows:—A peculiar and disagreeable smell, either of some essential oil or of acetic ether; an acid reaction to test-paper; a property of turning alcoholic solution of iodide of potassium brown with unusual rapidity; a high specific gravity, from superabundance of alcohol and water.

"The ether which has been both washed and redistilled is always the most uniform in composition, and especially so if the second distillation was conducted from quicklime, carbonate of potash, or caustic potash. These alkaline substances certainly retain the impurities, which appear to be of an acid nature, and leave the ether in the best possible state for use.

"The redistillation of ether is a simple process, and therefore it will be decribed. In dealing with ether, however, in any form, the greatest caution must be exercised, on account of its inflammable nature. Even in pouring ether from one bottle into another, if a light of any kind be near, the vapour is apt to take fire; and severe injuries have been occasioned from this cause.

"*Purification of Ether.*—Take ordinary rectified sulphuric ether, and agitate it well with an equal bulk of water, in order to wash out the alcohol; stand it for a few minutes until the contents of the bottle separate into two distinct strata, the lower of which—*i.e.*, the watery stratum—is to be drawn off and rejected. Then introduce caustic potash finely powdered, in the proportion of about one ounce to a pint of the washed ether; shake the bottle again many times, in order that the water—a small portion of which is still present in solution in the ether—may be thoroughly absorbed. Afterwards set aside for twenty-four hours (not longer), at the end of which time it will probably be observed that the liquid has changed to a straw-yellow colour, and that a flocculent deposit has formed in small quantity. Lastly, transfer to a retort of moderate capacity, supported in a saucepan of warm water, and properly connected with a condenser. On applying a gentle heat, the ether distils over quietly, and condenses with very little loss; care must of course be taken that none of the alkaline liquid contained in the body of the retort finds its way, by projection or otherwise, into the neck, so as to run down and contaminate the distilled fluid.

"A more economical plan of purifying ether is, without previous washing with water, to agitate with carbonate of potash or with quicklime, and redistill at a low temperature.

"In order to preserve ether from decomposition, it must be kept in stoppered bottles, quite full, and put away in a dark place; also the stoppers should be tied over with a bladder, or a considerable amount of evaporation will take place, unless the neck of the bottle has been ground with unusual care. After the lapse of some months, probably a certain amount of decomposition—evidenced by the liberation of iodine from iodine of potassium—will be found to have taken place, in spite of all precautions. This, however, is small in amount and not of a character to injure the fluid, except when very transparent films are employed, in which the amount of iodide of silver is reduced to a minimum.

"*Purification of Spirits of Wine.*—The object of this operation is to remove a portion of water from the spirit, and so to increase its strength. Alcohol thus purified may be added to collodion almost to any extent, without producing glutinosity and rottenness of film.

"The salt termed carbonate of potash is a 'deliquescent' salt—that is, it has a great attraction for water; consequently, when spirits of wine are agitated with carbonate of potash, a portion of water is removed, the salt dissolving in it and forming a dense liquid which refuses to mix with the alcohol, and sinks to the bottom. At the expiration of two or three days, if the bottle has been shaken frequently, the action is complete, and the lower stratum of fluid may be drawn off and rejected. Pure carbonate of potash is an expensive salt, and therefore a commoner variety may be taken. Even pearlash—a highly impure form of carbonate—will succeed, if no better is at hand.

"The quantity of carbonate of potash used may be about an ounce and a half to half a pint of spirit; an excess, however, does no harm.

"After the distillation is complete, a fluid is obtained containing about 90 per cent. of absolute alcohol, the remaining 10 per cent. being water. The specific gravity at 60° Fahrenheit should be about ·823; commercial spirit of wine being ·836 to ·840.

"*Preparation of the Iodising Compounds.*—These are the iodides of potassium, ammonium, and iron, also the double iodide of potassium and silver.

"*The Iodide of Potassium.*—Iodide of potassium, as sold in the shops, is often contaminated with various impurities. The first and most remarkable is carbonate of potash. When a sample of iodide of potassium contains much carbonate of potash, it forms small and imperfect crystals, which are strongly alkaline to test-paper, and become moist on exposure to the air, from the deliquescent nature of the alkaline carbonate. Sulphate of potash is also a common impurity; it may be detected by chloride of barium. Commercial iodide of potassium, however, is rarely so pure that no change whatever is produced by chloride of barium; therefore a mere opalescence or slight milkiness on adding the test solution may be disregarded, but if a decided white precipitate is formed, it will be better to reject the sample, or to purify it by solution in strong alcohol.

"A third impurity of iodide of potassium is chloride of potassium; it is detected as follows:—Precipitate the salt by an equal weight of nitrate of silver, and treat the yellow mass with solution of ammonia; if any chloride of silver is present, it dissolves in the ammonia, and after filtration is re-precipitated in white curds by the addition of an excess of pure nitric acid. If the nitric acid employed is not pure, but contains traces of free chlorine, the iodide of silver must be well washed with distilled water before treating it with ammonia, or the excess of free nitrate of silver dissolving in the ammonia would, on neutralising, produce chloride of silver, and so cause an error.

"Iodide of potassium may be rendered very pure by re-crystallising from spirit, or by dissolving in strong alcohol of specific gravity ·823, in which both sulphate and carbonate of potash are insoluble. The proportion of iodide of potassium contained in saturated alcoholic solutions varies with the strength of the spirit.

"*The Iodide of Ammonium.*—This salt may be prepared by adding carbonate of ammonia to iodide of iron, but more easily by the following process:—A strong solution of hydrosulphate of ammonia is first made, by passing sulphuretted hydrogen gas into liquor ammonia. To this liquid iodine is added until the whole of the sulphuret of ammonium has been converted into iodide. When this point is reached, the solution at once colours brown from solution of free iodine. On the first addition of the iodine, an escape of sulphuretted hydrogen gas and a dense deposit of sulphur take place. After the decomposition of the hydrosulphate of ammonia is complete, a portion of hydriodic acid—formed by the mutual reaction of sulphuretted hydrogen and iodine—attacks any carbonate of ammonia which may be present, and causes an effervescence. The effervescence being over, the liquid is still acid to test-paper, from excess of hydriodic acid; it is to be cautiously neutralized with ammonia, and evaporated by the heat of a water-bath to the crystallizing point.

"The crystals should be thoroughly dried over a dish of sulphuric acid, and then sealed in small tubes containing each about half a drachm of the salt.

"The writer invariably employs the iodide of ammonium for the purpose of iodising collodion, and finds that at the expiration of two years from the time of preparation the salt is still perfectly colourless.

"Iodide of ammonium is very soluble in alcohol; but it is not advisable to keep it in solution, from the rapidity with which it decomposes and becomes brown.

"The most common impurity of commercial iodide of ammonium is sulphate of ammonia; it is detected by its sparing solubility in alcohol.

"*The Iodide of Iron.*—Iodide of iron, in a state fit for photographic use, is very easily obtained by dissolving about a drachm of iodine in an ounce of 'proof spirit'—that is, a mixture of equal bulks of spirits of wine and water, and adding an excess of iron' filings. After a few hours, a green solution is obtained without the aid of heat. The presence of metallic iron in excess prevents the liberation of iodine and deposit of peroxide of iron, which would otherwise speedily occur.

"*Double Iodide of Potassium and Silver.*—In preparing this compound, first form iodide of silver by dissolving equal weights of iodide of potassium and of nitrate of silver in separate portions of rain or distilled water, and washing the resulting yellow precipitate upon a filter. The washing is to be conducted, first, with water to wash away the nitrate of soda, and afterwards with a small portion of alcohol to displace the water.

"Then digest the yellow mass with excess of iodide of potassium in spirits of wine, until a saturated solution of the double salt is obtained.

"An analysis of a saturated solution of double iodide of potassium and silver in alcohol of specific gravity ·836, gave, as the quantity of both salts present in one fluid ounce, iodide of potassium, sixty-four grains; iodide of silver, twenty-four grains. Therefore in the preparation one and a-half drachm of powdered iodide of potassium, and about twenty grains of iodide of silver, obtained by precipitating fifteen grains of nitrate of silver by an equal weight of iodide of potassium, may be digested for some hours in an ounce of the spirits of wine.

"*Iodide of Cadmium.*—This salt is formed by heating filings of metallic cadmium with iodine, or by mixing the two together with addition of water.

"Iodide of cadmium is very soluble both in alcohol and water; the solution yielding on evaporation large six-sided tables of a pearly lustre, which are permanent in the air. The crystalline form of this salt is a sufficient criterion of its purity."

The Collodio-Albumen Process.—Another process for facilitating the use of the collodion, has been brought forward by Mr. Ackland, a gentleman connected with Messrs. Horne and Thornthwaite's establishment, which, with their permission, we are enabled to give:—

"This is a process, invented by Dr. Taupenot, for obtaining negatives on glass, which bids fair to outrival all others, being easy of manipulation, and giving results of the most exquisite minutiæ and beauty. Glass plates, when prepared and excited by this process, may be kept at least a fortnight before being developed, and these plates when exposed in the frame may be developed immediately, or kept for days before commencing this operation. Indeed it is quite possible to prepare and excite a number of plates before leaving home to go on a tour of twelve or fourteen days; to expose the plates at any time or place during the journey, and bring them home to be developed.

"The manipulation may be said to consist of nine distinct operations:—

"1. *Cleaning the Plate.*—For which the directions already given will suffice.

"2. *Coating with Iodized Collodion.*—The collodion necessary to be used in this process must be one yielding good *negative* pictures—that supplied by Horne and Thornthwaite, under the name of negative collodion, answers admirably. This is supplied either ready iodized, or the collodion and iodizing in separate bottles. As this collodion becomes less sensitive, after being iodized a fortnight, it is advisable to iodize no more than will be used in that time—therefore, obtain the collodion and the iodizing solution separate, as the mode of iodizing this collodion is very simple. Half an ounce of the iodizing solution is mixed with one ounce and a half of collodion, and the mixture allowed to settle twelve hours before being used; and it is even advisable to pour off the clear solution into a perfectly clean bottle, in order to get rid of any insoluble matter which may fall to the bottom. The plate having been thoroughly cleaned, and received its final polish by the use of a prepared chamois leather, is coated with the negative collodion, which has been iodized at least twelve hours, and allowed to settle.

"3. *Exciting the Collodion Film.*—After the ether has evaporated, and the surface of the collodion appears set, the plate must be laid, collodion side upwards, on a glass dipper, and plunged, with *one downward movement*, into a bath filled to within an inch of the top with collodion bath solution, prepared by dissolving one ounce of nitrate of silver in two ounces of distilled water, and two grains of iodide of potassium in one drachm of distilled water; mix the two solutions and shake well together, until the precipitate which is first thrown down is redissolved; when this takes place, add fourteen ounces of distilled water, and two drachms of alcohol. On the addition of the water, a turbidness ensues, which must be removed by the solution being very carefully filtered through filtering-paper; and the filtered liquid should be clear and transparent, free from any deposit or floating particles, and must possess a slightly acid reaction of test-paper.

"In order to ascertain if the solution thus prepared possesses the necessary amount of free acid without superabundance, proceed to test and to correct it, if necessary. The solution must be carefully filtered through filtering-paper before being used. After the plate has been allowed to remain in the bath one minute, it is lifted out three or four times, in order to facilitate the removal of the *oily appearance* which the plate now presents. When the surface appears wetted uniformly, on being drawn out of the solution the plate is removed from the dipper, and the excess of solution drained off, and is then placed, collodion side upwards, on a fixing stand, and distilled or filtered rain water poured over the surface, so as to remove *as much as possible of the bath solution* from the surface. The plate is now removed from the fixing stand, the back well washed with water, and then placed nearly upright on blotting-paper, with the face against a wall for *one minute*, to drain. This and subsequent operations (except exposure in the camera) must be performed in a dark room.

"4. *Coating with Albumen.*—Having allowed the plate to drain one minute, place it again on a levelling stand, with the film upwards, and pour over it as much of the iodized albumen as the plate will hold, from a glass measure containing not more than enough of the albumen to coat two plates, pour off the excess into the measure and again cover the plate with albumen three separate times; ultimately, drain off as much as possible of the excess of albumen, and place the plate nearly upright against the wall, with the coated side inwards, to dry, which takes place in an ordinary temperature in about one hour.

"In coating with albumen, the presence of air-bubbles or dust must be guarded against. The former can easily be done by taking care, in pouring the albumen into the measure and on the plate, not to pour so as to generate air-bubbles in the liquid. But should any be detected, hold the plate horizontally and give it another coating of albumen; then incline the plate so that the bulk of the liquid shall pass over and carry off the bubbles with the running stream. Dust on the plate must be prevented by operating in a room as free from this photographic enemy as possible.

"In order to render the coating of albumen as uniform as possible, the plate must stand to dry on two or three layers of filtering-paper, and the upper surface must touch the wall at *one point only*, and not be allowed to rest against it along its entire upper edge.

"When the albumen coating is *thoroughly dry* (and not till then), the plate is ready to be excited; but if more have been prepared than are likely to be used for taking pictures on during the next ten days or fortnight, they may be stowed away in a plate box, ready to receive the sensitive coating at any time. The author's experience has led him to believe that these albuminized plates will keep good any length of time, as plates which had been coated a month, when excited, exposed, and developed, appeared to possess all the properties of recently prepared plates.

"5. *Exciting the Albumen Coating.*—Prior to the plates being excited they must be *thoroughly dry* and free from any particles of loose dust on the surface, back, or edge. Sufficient of the albumen bath solution must be filtered through filtering paper to fill a dipping bath of the required size, so that the plate can be immersed in it.

"The careful filtering of the fluid is very necessary in order to free it from any floating particles, and to separate the animal charcoal.

"A bath having been prepared by dissolving an ounce and a half of nitrate of silver in sixteen ounces of distilled water; adding one ounce of glacial acetic acid, with two drachms animal charcoal, which has been kept for use in a closely stoppered bottle—the plate is now taken and laid, albumen side upwards, on the dipper, and then lowered into a bath with *one steady downward movement*, where it is allowed to remain *one minute;* it is then taken out, the excess of liquid drained off, and placed on the fixing stand, with the albumen surface uppermost, and a stream of water poured over it for at least one minute, so as to remove every particle of the bath solution. This complete washing is very necessary, in order to prevent stains in the after development, which invariably takes place around the edges, if not thoroughly washed. The plate, having been thoroughly washed, is leaned against a wall to dry, or, if required for immediate exposure, may be dried on a plate of heated metal or foot-warmer; but in no case must the exposure in the camera take place until the surface is thoroughly dry.

"6. *Exposure in the Camera.*[*]—As before stated, this operation may take place immediately the plate is thoroughly dry after being excited, or a fortnight may intervene between the exciting and exposure, provided the plate is kept very carefully excluded from light and any chemical or sulphurous vapours, in a plate box adapted for that purpose, with the sensitive surface towards the back of the box. When the exposure is about to take place, or at any time previously, the camera backs may each have a plate placed in them ready for exposure; to do this, the camera back must be taken into the operating room and the door closed, so as to exclude all white light. The hinged flap of the camera back is opened, and the prepared plate laid, with its sensitive surface *downwards*, or next the sliding flap, so that its corners may rest on the silver wire corners of the plate frame previously placed within the camera back ready to receive it. The hinged flap is now closed and kept from opening by turning the flap button over it; the sliding flap is examined to see that it is pushed closely down so as to guard any access of light, and it is then ready to be placed in the camera, and may be taken into the open air with impunity. Should the exposure not take place immediately, or should the camera back have to be carried any distance, it is advisable either to wrap it up in a black cloth, or secure the flaps from the chance of coming open, during transit, by stout string being tied around the back.

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[*] Care must be taken that the direct rays from the sun shall not fall on the lens or enter the camera during the exposure of a plate.

"The focusing is conducted in the same way as usual, and the cap replaced on the lens; the focusing glass is now removed, and the camera back fitted into the same aperture, *with the sliding flap next the lens.* The sliding flap is pulled up to its fullest extent, placing the hand on the camera back to prevent it rising out of the camera with this action. The cap of the lens is then removed, so that the light may be admitted into the camera, and to fall on the sensitive surface of the plate. After the necessary time of exposure has taken place, the cap is replaced on the lens, the sliding flap is pushed down, and the camera back withdrawn from the camera; the plate can then be taken into the operating room to be developed, or this operation may be deferred for days, or even a week or more if convenient. The time of exposure in the camera varies according to the intensity of the light and the aperture and focal length of the lens; therefore, to give the exact time of exposure would be impossible, still it may assist the amateur if I give the time required in summer with full sunshine, and merely state that this time may be increased to double in winter or dull weather.

"In the ordinary sunshine of a summer's day the time of exposure will be—

"30 seconds with a lens of 4-inch focus and ½-inch stop.
"21 seconds with a lens of 4-inch focus and ⅝-inch stop.
" 5 seconds with a lens or 4-inch focus and 1¼-inch aperture, with no stop.
" 1½ minute with a lens of 6-inch focus and ½-inch stop.
" 4½ seconds with a lens of 6-inch focus and 2¼-inch aperture, with no stop.
" 2 minutes with a lens of 8-inch focus and ½-inch stop.
" 1¼ minute with a lens of 8-inch focus and ⅝-inch stop.
" 3¼ minutes with a lens of 10-inch focus and ½-inch stop.
" 2 minutes with a lens of 10-inch focus and ⅝-inch stop.
" 5 seconds with a lens of 10-inch focus, 3¼-inch aperture, with no stop.
" 6¼ minutes with a lens of 14-inch focus and ½-inch stop.
" 4 minutes with a lens of 14-inch focus and ⅝-inch stop.
" 2¼ minutes with a lens of 14-inch focus and ¾-inch stop.
" 8¼ minutes with a lens of 16-inch focus and ½-inch stop.
" 5¼ minutes with a lens of 16-inch focus and ⅝-inch stop.
" 2¾ minutes with a lens of 16-inch focus and ¾-inch stop.

"7. *Developing the Image.*—The camera back is taken into the operating room, from which all white light is carefully excluded, the plate removed from the camera back, and laid, albumen side upwards, on the fixing stand; as much distilled water is now poured on it as the surface will hold, taking care that *every part of the sensitive surface is covered with the liquid;* allow the water to remain on the surface for one minute, then pour off and drain slightly; replace the plate on the stand, and pour over the surface, so as thoroughly to cover every part, the pyrogallic solution, which must be *carefully filtered* just before being used; allow this to remain on the plate for one minute, then drain off into a perfectly clean measure, and add to it an equal bulk of silver developing solution; *mix these thoroughly* together with a glass rod, and then pour the mixed liquids over the plate; allow them to rest until the picture begins to appear, which generally takes about from three to five minutes; then pour off and on repeatedly, until the developing fluid becomes opaque, which then contains floating particles, and these, if allowed to do so, would settle on the plate, to the injury of the picture; but this may be prevented by brushing the surface with a camel's-hair brush frequently during the development. When this opacity of the developing fluid takes place, drain all the fluid off the plate, and thoroughly wash with water; then mix another quantity of pyrogallic and silver developing solution in the same proportions as before, and pour this on and off the plate as before, until the picture appears sufficiently intense, and the middle shades well brought out; when this takes place, drain off, and wash with water, so as to clean the surface thoroughly, and the plate is then ready for the next step, 'fixing the image.'

"Should the picture begin to develop in less than three minutes after the application of the mixed developing fluids, thoroughly drain the plate, and wash well with water; then continue the development with a solution of three parts pyrogallic solution, prepared by dissolving fifteen grains pyrogallic acid in seven ounces of distilled water, then adding two drachms glacial acetic acid mixed with two drachms of alcohol and one part silver developing solution, consisting of one drachm nitrate of silver, dissolved in seven ounces distilled water, adding two drachms acetic acid. Should the picture, however, not begin to appear in five minutes, the addition of half a drachm of the albumen bath solution to each ounce of mixed developing solution will be necessary, in order to obtain the middle shades and the required intensity.

"It may be stated, as a guide, that the best negatives which the author has produced occupied from ten to twelve minutes in developing.

"8. *Fixing the Image.*—The plate, having been thoroughly freed from the developing fluid by careful washing, is now placed on the fixing stand, and the surface covered by the fixing solution, prepared by dissolving two ounces hydrosulphate of soda in one pint water. This solution being poured over it, in a few seconds the yellow opalescent colour of the film will begin to disappear, and its complete removal may be hastened by blowing gently on the plate, so as to disturb the fluid.

"When every particle of yellowness has disappeared, the fixing solution is drained off, and the surface *thoroughly washed;* and it is then leaned against the wall to drain and dry.

"9. *Varnishing the Plate.*—The plate, being thoroughly dry, is ready to receive a coating of transparent varnish, in order to protect the albumen surface from injury during the printing process. To do this effectually, the plate must be held before a fire or over a lamp, until it is slightly warm all over; then pour over its surface 'Horne and Thornthwaite's negative varnish,' in the same manner as collodion is applied; allow the superfluous varnish to drain back into the bottle; hold the plate again before the fire until the whole of the spirit is evaporated; and, when cold, the plate is ready to be printed from, so as to produce any number of positive pictures on paper.

"It will be observed that, in describing this process, the operator has been supposed to be so situated, that, in case a second view of the same spot were required, he could return to his operating room, remove the plate which had been exposed from the camera back to the plate box, and place another in the camera back, ready for taking another view. But, unfortunately, this is not at all times practicable. We therefore require some means of removing the plates, after being exposed, from the camera back into the plate box, and substituting others in their stead, whilst we are in the open air.

"In order to effect this, the 'Field Plate Box' has been devised by Mr. Ackland, by the aid of which the plates may be removed from the box, exposed in the camera, and again returned into the box, without any possibility of access of light falling on it.

"This box is but a trifle larger than the ordinary one, and is furnished with two sliding bottoms, working in grooves, one over the other; the lower bottom has a grooved channel, into which the side of the camera back slides; the camera back has an aperture through the side, closed by a narrow slide, and the lower bottom of the field-box has a corresponding one. We now suppose the field-box to have been previously filled with excited glass plates, *having their sensitive sides towards the back of the box*, and the box lid closed. The bottom slide is now pushed on until the aperture is in a line with any particular groove of the field-box (which position is indicated by a numbered scale and index point). The camera back is then slid on to its place on the field-box, so that the hinged flap is towards the front of the box, and its narrow slide drawn out. The upper slide is then withdrawn, and the box inclined, so that the plate in that groove opposite the aperture in the lower slide may pass through into the camera back. When this has taken place, push in the narrow slide of the camera back, invert the box, and push in the inner slide; then withdraw the camera back from its channel, and expose the plate in the camera. When this is done, slide the back again into its channel, draw out the inner box slide, then the narrow camera back slide, invert the box, and the plate will then leave the camera back and pass into the field-box, occupying the same groove as before.

"In order to get out another plate, slide the lower bottom, so that the index points to the number on the scale, as that of the groove in which the required plate is situate. Then proceed as before directed."

Dr. Mansell, of Guernsey, recommends, for changing plates in the open air, a bag made of three thicknesses of yellow glazed calico, one yard wide and one and a half yard long. Into this bag, the plate box containing the sensitive plates, the camera back, and the head, shoulders, and arms of the operator are placed. The bag is then tightly tied around the waist by tapes inserted into its neck. In this the operator can change his plates from the box to the back, or *vice versâ*, with impunity, as the yellow material prevents the admission of any rays that would damage the plates.

The foregoing process will be found very useful to travelling photographers, especially to those who do not use large glasses, as the weight of the latter would be rather an incumbrance; but by means of a light spring hand-cart, that difficulty could be got over. I must say that Mr. Ackland's plan for changing the glass plates, is one of the most ingenious I have ever seen.

Gutta-percha as a Sensitized Medium.—I shall now beg leave to introduce to the reader a new substance in photography, but as I have not had an opportunity of testing its capabilities I must make use of the inventor's words; even this will not be so easy, as it is difficult to say who is the inventor, because, although Mr.

Archer has taken out a patent for the use of the substance, the Rev. Mr. J. B. Reade has communicated the self-same process to the Photographic Journal; and it is rather singular, in reference to patents, that the same gentleman made almost the same discoveries in the calotype that Mr. Fox Talbot made, and actually made them known *before* Mr. Talbot patented his discoveries.

The substance above alluded to is gutta-percha, and the following is the substance of a paper read to the Photograpic Society in November 1855, by Mr. Reade.—

"It is known to many," he says, "that a substitute for glass is a great desideratum to the practical photographer. The cost of glass is a serious diminution to the profits of the professional artist, and loss from breakage, especially when many valuable negatives are destroyed, compels a man to ask whether he cannot be supplied with an article as clear as glass and as tough as leather. I venture to offer gutta-percha as a substitute. It possesses the good qualities of glass in its perfect transparency and evenness of surface, while its cost is trifling, and its cohesion perfect.

"My experiments have recently been carried on in conjunction with my friend Mr. Millar, the resident medical superintendent of the Bucks Lunatic Asylum at Stone, and we can now present gutta-percha in such a form as warrants us to ask for the opinion of photographers upon it.

"In the first place we dissolve gutta-percha in benzole, one of the peculiar hydrocarbons of coal-tar naphtha, or in chloroform. Thirty grains of gutta-percha added to an ounce of either solvent, is poured upon a plate of glass, and the excess drained off into the bottle, as in the use of collodion, produces the film upon which we have worked.

"The benzole dissolved the common sheet gutta-percha of the shops (not a perfectly pure article) with great readiness, upon the application of heat; immersing the bottle in hot water being sufficient. The colouring matter, producing the well-known pinkish tint, fell to the bottom of the bottle, and above it was a solution as clear and colourless as water.

"This was poured upon a glass plate as I have described, and immediately dried, or nearly so, by holding it over a spirit-lamp. This precaution for securing an evenness of surface is more necessary with the benzole then with the chloroform solvent, though its advantage even in the latter case is apparent. The film adheres perfectly to the glass, and has no tendency to separate from it on subsequent immersion in the nitrate bath if the edges of the glass are roughened; but if, as in some cases, they are smooth and polished, it is advisable, when the film is dry, to secure it firmly and certainly by passing the four edges of the coated glass through the flame of a spirit-lamp. By this method about one-eighth of an inch of the film is dissolved, or nearly so, all round the surface of the glass, and no separation can be produced by any amount of immersion in water. This film, now firmly fixed upon the glass, is treated in the subsequent process as if it were glass.

"The iodized collodion is poured upon it and sensitized in the usual way, and the picture is taken, developed, fixed, and varnished. The point of a knife is now carried round the edge of the glass for the purpose of scraping off the small portion of the film which had been semi-dissolved by heat to secure its perfect adherence. It is then placed in water for a minute or two, one edge of the film is slightly raised so that the fingers can take hold of it, and the whole separates with great facility and floats. By raising the glass up to it, it can be taken out on its surface, placed with the film downwards on blotting-paper, and the glass drawn from it. When dry, place the film between two pieces of paper, hold it up to the light and cut the paper—at the same time the film, which is perfectly visible through the paper—to any required size.

"We have now a negative ready for the printing frame, taken on a material as durable and manageable as glass, but occupying only a small portion of its space, and perfectly free from the peculiar risks which so often put valuable negatives altogether *hors de combat*.

"Benzole having the property of becoming solid at a temperature of 32°, the gutta-percha dissolved in it, unless it be a very thin film, has a tendency to become opaque, which might possibly interfere with the subsequent printing from the negative. This defect is wholly avoided by dissolving the benzole film, when dry, in chloroform, and then using the chloroform film, which never becomes opaque, for the purpose proposed. I understand from Mr. De la Rue, that one of the products of Birmese naphtha, which he is about to introduce, will form the best solvent, and produce a thick transparent film at all temperatures. The pure chloroform solution obtained, as above described, may be used, according to the happy suggestion of Mr. Pollock, as a protecting varnish for positives, and if applied to both sides of the picture, injury from atmospheric influence seems scarcely possible.

"I may add that it is not difficult to iodize the solution of gutta-percha itself, taking pictures upon it quite independently of the use of collodion, and also that a mixture of collodion and gutta-percha is not bad; but I think, upon the whole, the proper place for the gutta-percha to occupy is this which I propose, as a substitute for the glass. We then deal with collodion, which is by far the best preparation put into our hands for sensitizing, and upon which we take pictures. We deal with it in the usual way, and put upon the film as if we were putting upon glass. You are then quite independent of glass, and may keep a stock in a small portfolio.

"Perhaps I may be allowed, in addition, to state, that when the film is of a certain degree of thinness it has a tendency, when perfectly dry, to curl; but if you breathe upon it that tendency ceases, and it remains perfectly flat, and can be put into the printing frame with the greatest facility. In taking pictures you would adopt practically a useful thickness."

Mr. Archer says in allusion to his patented process:—"Ever since my introduction of the collodion process, it has been my desire to do away with the inconvenience of glass for negatives.

"According to my early publications, when on a journey, I used to remove the collodion film from the glass, roll the pictures up between blotting-paper, and expand them again on glass when at home; but this occupied much time, and required very delicate manipulation.

"These difficulties induced me to try experiments with a variety of substances likely to preserve the delicacy of the picture on the collodion film, and to be sufficiently strong to bear handling when in use.

"After much labour I have succeeded in my object, and in August last I patented my process, which I hope will be found to remove the only great impediment to the universal use of collodion in photography. The material used is a solution of gutta-percha in benzole. Other solvents can be used, but this is preferable to any.

"There are two methods of applying this solution of gutta-percha (both included in the patent) to accomplish the object in view, viz., the removal of the collodion film from the glass. I will describe them in detail.

"The first method is this:—Pour on the clean glass plate a quantity of the solution of gutta-percha, in a similar manner as for coating the glass with a film of collodion. When this film is dried, the iodised collodion is poured on and immersed in the silver bath. The plate is exposed, developed, and fixed. The glass plate, with gutta-percha and collodion film attached to it, is immersed in a vessel of cold water, which presently causes the two combined films to separate readily from the glass.

"The second method:—Prepare the glass with iodised collodion, and proceed with the process in the ordinary manner.

"When the collodion picture is dried, pour on to it the solution of gutta-percha; when the plate is covered, hold it in a horizontal position for about a minute to thicken. Draw off very gently through a funnel into the bottle the excess of solution, and gradually raise the plate vertically over the funnel.

"The benzole will evaporate rapidly, leaving on the collodion picture, and in intimate contact with it, a coating of gutta-percha.

"The plate must now be gently held with its back towards a clear fire, to accelerate the hardening of the gutta-percha and to prevent its chilling on the surface.

"When cold, the plate is immersed in a vessel of cold water, which causes the combined films to separate, in one sheet, from the glass."

"In this operation the benzole solution does not come in contact with the glass, nor is the surface of the glass in any way injured by its application to the collodion.

"Thus the glass can be used again after the ordinary cleaning. One great objection to the first method is, if the collodion picture be not successful, the gutta-percha coating is lost; whereas, in the second, the solution is only applied to a perfect picture, or such as the operator wishes to preserve.

"Another objection to the first method is, the great difficulty in getting the gutta-percha film sufficiently even when used thick enough to support the film."

The only objection I see to the process just noticed is, that the gutta-percha film will not stand the heat of a summer's sun, as I have seen solid gutta-percha, and pretty thick too, melt in the heat of summer; and I must say that I should not like to see a negative that I set some value on melt, and perhaps draw out to about twice its length.

It may not be out of place to describe here the camera constructed by Mr. Archer, for out-of-door practice with collodion. It is a wooden box eighteen inches long and twelve inches wide and deep. In front is a sliding door with a circular opening to admit the lens; this sliding door enables the operator to raise or depress the point of view. The camera has in the sides a hole into which sleeves of India-rubber cloth are fixed, furnished with India-rubber bands, into which the hands of the operator are admitted, the bands closing at the wrists and excluding the light while he arranges the collodion frame.

The back of the camera has a hinged door, fitted at its upper part with an opening of just sufficient size for the eyes, and shaped so as to fit close to the face. A black cloth is tied round this end of the camera, to prevent any ray of light penetrating the opening in the top of the instrument. Near the front is inserted a frame of yellow glass hinged like a door to admit a regulated yellow light. The interior of the box is furnished with a sliding frame to support the ground glass, the bath and the prepared plate, with a focusing slide, by which images of from three to fifteen inches can be obtained, the bottom being furnished with a gutta-percha tray, one inch deep, to hold the washings when in operation.

This instrument allows of the preparation of the most sensitive surfaces on the spot, of their immediate use, ready development, and fixing of the image at once.

Mr. Clarke's Siphon.—The following ingenious contrivance of Mr. R. T. Clarke may not be out of place here, he calls it "*A bottle siphon for the silver bath,*" and he uses it for the purpose of emptying his nitrate bath when he has finished working:—

"The upright baths are very awkward things, as made at present, to pour from. I employ a siphon bottle such as is here represented (Fig. 74).

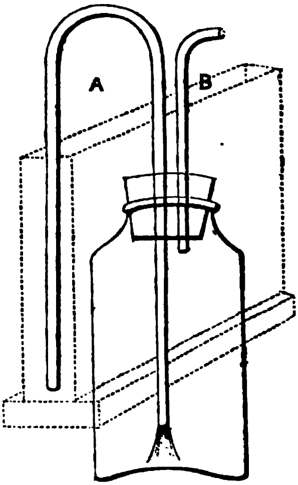


Fig. 74.

"Place the short leg of the siphon A in the bath, which must be raised on a block or otherwise. Exhaust the air from the bottle by the mouth-tube B, and you will draw off your bath into its bottle at once, without danger to yourself or loss of liquid. The lips must be withdrawn of course as soon as the siphon begins to act. You have only now to take out the apparatus, which is merely a cork with two pieces of quill tubing, and replace the glass stopper."

Before dismissing the subject of collodion, I may add, that, with careful manipulation, a total absence of all flurry, performing each part gently, extreme cleanliness, care that there is no floating dust in the camera or dark-room, great care in focusing, proper attention to light and shade, bath, collodion, and developing solution well filtered, measures and vessels well cleaned, absence of any fluid left in the frame by a former plate, gently raising up and shutting down the slide, a proper length of exposure, and, above all, *observation*, success is *certain*. Before concluding, I shall describe a very useful piece of apparatus nearly identical with Mr. Clarke's siphon, which is used by Mr. Hardwich for clearing collodion. The collodion being iodized some hours previously, and allowed to settle down and become clear in a bottle with a large mouth, in which a cork with perforated holes for two glass tubes is placed, as represented in Mr. Clarke's drawing. By gently blowing at the point of the shorter tube, the other glass tube is filled, and the fluid drawn off more closely and cleanly than could be done by simply pouring from one bottle to another. I shall conclude my remarks on this part of the science. The next will be—

On the Fixing and Colouring of Positives.—As this is a subject of vital importance to photography (their being but little use in producing first-rate negatives if you cannot from them obtain beautiful and lasting copies), it has met with an unusual amount of study and experiments at the hands of some of the most eminent photographers. Among these no man has given the subject more consideration than Mr. Hardwich. I again make use of his pages, giving, in some instances, his own words, in others their substance.

This subject Mr. Hardwich divides into five sections:—1st, Positive printing by the ordinary direct process; 2nd, Mr. Sutton's mode of toning positives; 3rd, Positive printing by the negative process; 4th, Remarks on the fading of positives; 5th, On printing enlarged or reduced positives, transparencies, &c., which I shall briefly notice in their turn.

Positive Printing upon Chloride of Silver.—This includes preparation of sensitive paper—of fixing and toning baths—manipulatory details of the process.

In the preparation of sensitive paper there are three kinds of surfaces, viz., albuminized paper, plain salted paper, and paper prepared with serum of milk, which may be used. A photographic paper should be very smooth and uniform in texture; of equal thickness in each part, and free from spots. These spots consist usually of small metallic particles, which, when the paper is rendered sensitive, act as centres of chemical action and spoil the effect.

The foreign papers, French and German, are porous and sized with starch, the English being dense and sized with gelatinous animal matter, which gives a brown tint to the reduced chloride of silver in the same manner as albumen. The density of English papers makes the fixing and toning of the positives a slower process than when foreign papers are used. There is also a tendency to curl up when laid upon the liquid for albuminizing, and Mr. Hardwich recommends the thin negative papers of Canson and de la Rive, or the *papier Saxe*, where they can be obtained. A difference in smoothness between the two sides of the paper is perceptible, which may be detected by holding the sheet in such a manner that the light strikes it at an angle; the wrong side is that on which broad wavy bands are seen, caused by the strips of felt on which the paper was dried.

Preparation of Albuminized Paper.—This includes the salting, albuminizing, and sensitizing with nitrate of silver.

Take chloride of ammonium, or pure chloride of sodium fifteen grains, water (distilled if at hand; if not rain water) one ounce.

Mix any number of ounces according to this formula, and add a third part by measure of the whites of new-laid eggs. Then with a bundle of quills tied together beat the whole into a perfect froth. As the froth forms, it is to be skimmed off and placed in a flat dish to subside, when it should form a perfectly homogeneous mass. The success of the operation depends entirely upon the manner in which this part of the process is conducted. If the albumen is not thoroughly beaten, flakes of animal membrane will be left in the liquid, and will cause streaks upon the paper. When the froth has partially subsided, transfer it to a tall and narrow jar, and allow it to stand for several hours, that the membranous shreds may settle to the bottom. Then pour off the upper portion, which should now be clear and fit for use. Albuminous liquids are too glutinous to run well through a paper filter, and therefore it is better to clear them by subsidence.

To apply the albumen, pour a portion of the solution into a flat dish to the depth of half an inch. Then, having previously cut the paper to the proper size, take a sheet by the two corners, bend it into a curved form, convexity downwards, and lay it upon the albumen, the centre part first touching the liquid and the corners being lowered gradually. In this way all bubbles of air will be pushed forward and excluded. One side only of the paper is wetted; the other remains dry. Allow the sheet to rest upon the solution for one minute, and then raise it off, and pin up by two corners. If any circular spots, free from albumen, are seen, caused by bubbles of air, replace the sheet for the same length of time as at first.

Most practical operators lay stress upon removing the sheet from the albumen speedily; and it certainly is the case that if you take a thick porous paper, like Canson's positive, and leave it upon an albumen bath for a long time the surface is roughened and irregular from imperfect absorption of the last layer of liquid.

Albuminized paper will keep any length of time in a dry place. Some have recommended to press it with a heated iron, in order to coagulate the layer of albumen upon the surface; but this precaution is unnecessary, since the coagulation is perfectly effected by the nitrate of silver used in the sensitizing. Also, it is doubtful whether a layer of dry albumen would admit of coagulation by the simple application of a heated iron.

To Render the Paper Sensitive.—This operation must be conducted by candle or yellow light, and with a solution of nitrate of silver, sixty grains; distilled water, one ounce. If the sample of nitrate of silver contains much free nitric acid it may be of service to neutralize it with carbonate of soda, filtering out the excess of white carbonate of silver, and then adding one or two drops of glacial acetic acid.

Prepare a sufficient quantity of this solution, and lay the sheet upon it in the same manner as before. Three minutes contact will be sufficient with the thin negative paper, but if the Canson positive paper is used, four or five minutes must be allowed for the decomposition. The papers are raised from the solution by a pair of bone forceps or common tweezers tipped with sealing-wax, and hung up to dry. A small strip of blotting-paper suspended from the lower edge of the paper will serve to drain off the last drop of liquid.

After the solution of nitrate of silver has been in use some time, it becomes discoloured from a partial formation of sulphuret of silver. The brown colour may be removed by the employment of animal charcoal, or the white china clay, or "pipe-clay."

After a large quantity of paper has been sensitized, add fresh nitrate of silver in the proportion of about ten grains to the ounce, in order to keep the bath at its original strength.

Sensitive albuminized paper, prepared as above, will usually keep one or two days, if protected from the light; but afterwards it turns yellow from partial decomposition.

Preparation of Plain Salted Paper.—Take of purified gelatine one grain; chloride of sodium or ammonium, ten grains; water, one ounce. Either of the foreign papers may be used for this formula—Canson's positive and papier Saxe being especially recommended. Towgood's positive gives a fine brown nearly approaching to black; it must be salted in the same manner as the others.

Weigh out the proper quantity of gelatine for the required number of ounces, and dissolve it in a small bulk of warm water. Then add the remainder of the water and the salt. The mode of salting the paper is the same as for albumen, but if the weather is cold, it will be well to hang the sheets near to the fire, to prevent any gelatinizing, which might otherwise occur.

Mode of Sensitizing the Salted Paper.—Gelatine paper may be sensitized by floating upon the ordinary sixty-grain solution of nitrate of silver; or with the ammonio-nitrate of silver prepared as follows:—Take of nitrate of silver, eighty grains; distilled water, one ounce. Dissolve the nitrate of silver in one-half of the total quantity of water. Then take a pure solution of ammonia and drop it in carefully, stirring meanwhile with a glass rod. A brown precipitate of oxide of silver first forms, but on the addition of more ammonia it is redissolved. When the liquid appears to be clearing up, add the ammonia very cautiously, so as not to incur an excess. In order still further to secure the absence of free ammonia, it is usual to direct, that when the liquid becomes perfectly clear, a drop or two of solution of nitrate of silver should be added, until a slight turbidity is again produced. Lastly, dilute with water to the proper bulk. If the crystals of nitrate of silver employed contain a large excess of free nitric acid, no precipitate will be formed on the first addition of ammonia. The free nitric acid, producing nitrate of ammonia with the alkali, keeps the oxide of silver in solution. This cause of error, however, is not likely to happen frequently, since the amount of nitrate of ammonia required to prevent all precipitation would be considerable. From the same reason, viz., the presence of nitrate of ammonia, it is useless to attempt to convert a nitrate bath, already used for sensitizing, into ammonio-nitrate.

Ammonio-nitrate of silver should be kept in a dark place, being more prone to reduction than the nitrate of silver.

Sensitizing Salted Paper with Ammonio-Nitrate.—Most operators prefer brushing on the solution of ammonio-nitrate, the properties of the solution being altered by the reaction with the salt, free ammonia being thus formed in the ammonio-nitrate bath, which has the effect of changing the half-shadows of the print to a reddish-pink tone. Even in brushing the same ammonia is not to be used too often. Brushes are sold manufactured purposely for applying silver solutions; but the hair is soon destroyed, unless care is taken to keep the brush clean. In sensitizing paper by brushing, lay the salted sheet upon blotting-paper, and wet it thoroughly by drawing the brush first lengthways and then across. Allow it to remain flat for a few minutes, in order that a sufficient quantity of the silver solution may be absorbed, and then pin up by the corner in the usual way.

Ammonio-nitrate papers cannot be kept long; they become discoloured after the lapse of a few hours.

Gelatine paper sensitized with plain nitrate of silver will remain good for several days; it turns a little yellow, but this is removed by the toning bath.

Preparation with Serum of Milk.—The serum of milk is prepared as follows:—Take pure milk from the cow, and curdle it by a piece of rennet, or if that cannot be obtained, by dropping into it a little acetic acid or common vinegar. The quantity of vinegar required will, perhaps, be about two or three drachms to the quart of milk, which must be boiling hot at the time the acid is added. The caseine coagulates immediately, and is to be strained out through a cloth and rejected. When the serum has become nearly cold the white of an egg is added, previously beaten up in a cup to insure thorough mixture; then place the serum in a pipkin over a slow fire, and heat it to ebullition. The albumen coagulates, forming a fine network, and carrying up with it globules of oil, thus clearing the liquid. When it is cold, strain again through muslin or calico, and afterwards through blotting-paper. The latter filtration is often tedious, and occupies several hours; if started over night in a large filter, it will probably be completed by the morning. The serum, when properly prepared, should have a straw-yellow tint, and be perfectly clear and transparent.

The serum being thus prepared, take of chloride of ammonium ten grains, of the serum of milk one ounce; to this add one grain of gelatine thoroughly dissolved in a drachm and a half of boiling water; pour the hot solution into the serum, and stir with a glass rod or silver spoon; then add one ounce of alcohol to each ten ounces of the solution.

Sensitizing the Serum Surface.—Lastly, measure the bulk of the liquid, and dissolve the salt in the proportion of ten grains to each ounce.

The papers which appear to give the finest tints with serum of milk are Le Rive's negative, papier Saxe, and Canson's positive paper. Towgood's positive paper gives a shade of brown, very warm and pleasing.

The sheets are laid upon the salting bath in the usual way, and allowed to remain from one to two minutes, according to the thickness and degree of porosity of the paper, the thin papers requiring less time.

They are sensitized on the nitrate bath of sixty grains to the ounce of water. From two to three minutes' contact will be sufficient. The serum discolours the nitrate of silver to a certain extent, but not in so marked a manner as albumen.

Papers prepared by this method turn yellow more quickly than usual; they should therefore be sensitized, if possible, only a few hours before use. Mr. Shadbolt recommends the addition of acetic acid to the nitrate of silver bath, to obviate the tendency of albuminized and other papers to discolour by keeping.

Hints in selecting from the above Formulæ.—Albuminized paper is, perhaps, the most generally useful; it gives a warm, bright appearance to the shadows, and the tint is of a pleasing brown.

Serum of Milk Paper gives fine purple tones, and is free from the glossiness of surface which many object to in albumen. Plain salted paper is recommended for obtaining pure black tones suitable for portraits and engravings. The negatives, however, should be intense, or the result will be inferior; good brown tones may be obtained with a comparatively pale negative, but not the finest blacks. Canson's positive paper and papier Saxe are, perhaps, the best for black tints.

Ammonio-Nitrate Paper gives blacks possessing great depth and brilliancy, but it is troublesome to manipulate with, and requires more care than the others.

Preparation of the Fixing and Toning Solutions.—Bath for fixing and toning positive proofs may be prepared in either of the following ways:—By perchloride of iron, with iodine, and with chloride of gold.

1. *With Perchloride of Iron.*—Dissolve four ounces of hyposulphite of soda in seven ounces of water, and thirty grains of nitrate of silver in one ounce of water. Pour into the solution of hyposulphite by degrees, stirring all the time, six drachms of perchloride of iron. The addition of this salt produces a fine purple colour, which soon disappears. When the liquid has become again colourless, which it does in a few minutes, add the dissolved nitrate of silver, stirring briskly. Perfect solution will take place without any formation of black sulphuret.

A toning bath prepared with chloride of iron will be ready for use twelve hours after mixing, but it will be still more active at the expiration of a week. The solution soon becomes acid to test-paper, and milky from a deposit of sulphur; this may be removed by filtration, but it is scarcely necessary to filter out any solid deposit, as the close texture of paper upon which positives are printed prevents it from doing injury.

The bath may be employed either in an acid or neutral state. If the weather is cold, probably the colouring action will be slow, and in that case it is best to allow the acid to remain. But if the thermometer indicates 60° or higher, the colouration of the print is effected with more rapidity, and there is danger of the half-tones being eaten away by the acid bath; and, therefore, it will be advisable to neutralize it by shaking up the solution for five minutes with as much powdered chalk or whiting as will stand upon a shilling, and afterwards allowing it to settle down, or filter it through blotting-paper. Chalk is the only practicable remedy, because the solution contains protochloride of iron, which on the addition of an alkali forms first oxide, and then, by reacting on the sulphuretted principles present, sulphuret of iron.

For this reason ammonio-nitrate prints cannot be toned in a solution prepared with chloride of iron.

After the bath has been neutralized, there is a constant tendency to a return of the acidity.

2. *Fixing and Toning Bath with Iodine.*—Dissolve the thirty grains nitrate of silver in an ounce of the water, as before. Then, from four ounces of hyposulphite of soda, weigh out carefully hyposulphite of soda sixty grains. Dissolve in an ounce of the water, and throw into it thirty grains commercial iodine. Agitate the vessel until the whole has disappeared, which will happen in the course of a few minutes. If after the solution of the iodine a brown tint is acquired, there is an excess of iodine; in that case, cautiously add hyposulphite of soda, a single grain at a time, until the liquid becomes colourless; then pour in nitrate of lead forty grains, previously dissolved in an ounce of the water. The addition of nitrate of lead causes the separation of the greater portion of the iodine in the form of yellow iodide of lead, which is useless, and may be rejected. Throw the whole upon a paper filter, and allow it to drain for a short time; then pour upon it by degrees two ounces of water, in order to wash out as much of the soluble tetrathionate of soda as possible. When all has run through, add three ounces of water; dissolve the hyposulphite of soda, and mix in the nitrate of silver solution with continual stirring as before.

This bath is not very active when first prepared, probably on account of a little iodide of lead remaining dissolved; but at the expiration of a few days or a week it will yield very fine tones, and is then superior to Formula No. 1.

It will continue in good working order for about a month or six weeks, but after that time loses its activity to some extent, even if it be not used. The immersion of prints by removing sulphur has the same effect, the tones being produced more slowly, and a fresh addition of iodine being required.

3. *Fixing and Toning Bath with Chloride of Gold.*—Dissolve four ounces hyposulphite of soda in four ounces of water, solution of chloride of gold, a quantity equivalent to four grains, in three ounces of water; thirty grains nitrate of silver in one ounce. Pour the diluted chloride by degrees into the hyposulphite, stirring with a glass rod; and afterwards the nitrate of silver in the same way. This order of mixing the solutions is to be strictly observed; if it were reversed, the hyposulphite of soda being added to the chloride of gold, the result would be the reduction of metallic gold. The difference depends upon the fact, that the hyposulphite of gold which is formed is an unstable substance, and cannot exist in contact with unaltered chloride of gold. It is necessary that it should be dissolved by hyposulphite of soda immediately on its formation, and so rendered more permanent by conversion into a double salt of soda and gold.

A toning bath prepared with chloride of gold is most active at the expiration of a few days after mixing. On keeping for some weeks it loses much of its efficacy by a process of spontaneous decomposition, and requires the addition of fresh chloride of gold.

Photographic Printing.—These include the exposure to light, or printing, properly so called; the fixing and toning; and the washing, drying, and mounting of the proof.

The Exposure to Light.—For this purpose frames are sold, so constructed that they admit of being opened at the back, in order to examine the progress of the darkening by light, without producing any disturbance of position.

Simple squares of glass, however, succeed equally well, when a little experience has been acquired. They may be held together by the wooden clips sold at the American warehouses at one shilling per dozen. The lower plate should be covered with black cloth or velvet.

Supposing the frame to be employed, the shutter at the back is removed, and the negative laid flat upon the glass, collodion side uppermost. A sheet of sensitive paper is then placed upon the negative, sensitive side downwards, and the whole tightly compressed by replacing and bolting down the shutter.

This operation may be conducted in the dark room; but unless the light is very strong, such a precaution will scarcely be required. The time of exposure to light varies much with the density of the negative and the power of the actinic rays, as influenced by the season of the year and other obvious considerations. As a general rule, the best negatives print slowly; whereas negatives which have been under-exposed and under-developed are more rapid.

In the early spring or summer, when the light is powerful, probably about ten to fifteen minutes will be required; but as much as three-quarters of an hour may be allowed in the winter months, even in the direct rays of the sun.

It is always easy to judge of the length of time which will be sufficient, by exposing a small slip of the sensitive paper, unshielded, to the sun's rays, and observing how long it takes to reach the coppery stage of reduction. Whatever the time may be, about the same will be occupied in the printing, if the negative is a good one.

When the darkening of the paper appears to have proceeded to a considerable extent, the frame is to be taken in and the picture examined. If squares of plate glass are used, in place of a printing-frame, to keep the negative and sensitive paper in contact, some difficulty will be experienced at first in returning it precisely to its former position after the examination is complete; but this will easily be overcome by practice. The finger and thumb should be fixed on the lower corners or edge, and the plate raised gently.

If the exposure to light has been sufficiently long, the general aspect of the print appears slightly darker than it is intended to remain. The toning bath dissolves away the lighter shades and reduces the intensity, for which allowance is made in the exposure to light. A little experience soon teaches what is the proper depth to print; but the following general rules may be useful as a guide. The acid toning bath, prepared with iodine or perchloride of iron, dissolves away the lighter shades more than the neutral bath, with chloride of gold. When the proofs are to be immersed for a long time in order to secure black tones, it is necessary to over-print more strongly than when the purple tints are desired.

If, on removal from the printing-frame, a peculiar spotted appearance is seen, produced by unequal darkening of the chloride of silver, either the nitrate bath is too weak, the sheet removed from its surface too speedily, or the paper is of inferior quality.

On the other hand, if the general aspect of the print is a rich chocolate-brown in the case of albumen, a dark slate-blue with gelatine or ammonio-nitrate paper, or a reddish-purple with paper prepared on serum of milk, probably the subsequent colouration will proceed well.

If, in the exposure to light, the shadows of the proof become very decidedly coppery before the lights are sufficiently printed, the negative is in fault. Ammonio-nitrate paper is particularly liable to this fault of excess of reduction, and especially so if the light is powerful; hence it is best, as a rule, not to print by the direct rays of the sun. This point is important also, because the excessive heat of the sun's rays often cracks the glasses by unequal expansion, and glues the negative firmly down to the sensitive paper.

The Fixing and Toning of the Proof.—The print may be immersed in the toning bath immediately on its removal from the frame; but no injury results from putting it aside for a time, if it be kept in a dark place.

After its immersion, move it about for a short time to displace air-bubbles, which, if allowed to remain, produce spots. In a few minutes the rich chocolate-brown or violet-blue tints disappear, and the red tones take their place.

Albumen proofs become brick-red; gelatine and ammonio-nitrate a brownish-black. If the colours are unusually pale and red, very probably the silver bath is too weak, or the quantity of chloride of ammonium used was insufficient; a pink tint in the case of ammonio-nitrate pictures, if very marked, generally gives a bad result. The action of the bath must be continued until the desired effect is obtained. This may happen in from twenty minutes to half an hour, if the solution is in good working order and the thermometer at 60°; but much depends upon the temperature.

The purple tones are an earlier stage of colouration than the black tones, and therefore the latter require more time. It must be borne in mind, however, that prolonged immersion in a tetrathionate bath, prepared with iodine or perchloride of iron, is decidedly favourable to yellowness of the whites; and with an albumen print it will be difficult to obtain pure whites if the colouring is carried beyond the purple stage. With the gold bath the action may be pushed further with impunity.

Ammonia-nitrate and gelatine papers are less prone to turn yellow than paper prepared with albumen. The yellow colour is not often sëen decidedly whilst the print is in the bath, but it comes out in the after-processes of washing and drying.

The error most frequently committed in colouring positive proofs is, continuing the action of the hypo bath for too long a time with the idea of obtaining darker tones. The injurious effects so caused are most evident when the print has been washed and dried; it is then seen that much of the brilliancy and richness of the tint is lost, whereas if the proof had been removed at an earlier period it would have been improved. These remarks apply in all cases, but especially so to the tetrathionate bath without gold.

Some advise that on removal from the bath the print should be soaked in new hypo for ten minutes, in order to complete the fixation; but this precaution is not required with solutions of such a strength as those given in the formulæ. An analysis of an old hypo bath, which had been very extensively used, indicated only ten grains of hyposulphite of silver to the ounce, so that it was at that time far from being saturated.

With a bath prepared by the perchloride of iron process, if any red deposit upon the surface of the print (peroxide of iron) occurs during the washing, a portion of the protochloride of iron may be removed from the fibres of the paper by soaking in new hypo.

The addition of fresh crystals of hyposulphite of soda occasionally, in order to keep up the strength of the bath, is a safe plan to adopt, the exact quantity added not being material.

On the Washing Positive Proofs.—It is essential to wash out every trace of hyposulphite of soda from the print if it is to be preserved from fading, and to do this properly requires considerable care.

Always wash with running water when it can be obtained, and choose a large shallow vessel, exposing a considerable surface in preference to one of lesser diameter. Nothing is better than the ordinary leaden sink carefully washed out, and a tube inserted into the exit pipe, that the water may not flow away until it reaches to the depth of a few inches. A constant dribbling of water must be maintained for about five or six hours, at the end of which time the tap may be stopped, and the print left in the water until the following morning. This is the plan pursued by the author, and found by him to be sufficient for prints toned either with or without gold.

Even in washing by running water, however, some precautions must be observed; the prints should not lie together too closely, or the water does not find its way between them. You may easily prove this by wetting five or six prints fresh from the frame, and, having placed them in a shallow pan of water, turning on the tap until the water runs off quite clear; then separate the papers from each other, when a milky liquid will pass out from between them, thus showing that a stationary layer of fluid existed at that point. Therefore, in washing, the prints should be kept as much as possible separate from each other, and should be constantly moved and turned over to expose every part of the surface to the action of the running water.

When running water cannot be obtained, proceed as follows:—First wash the print gently, to remove the greater part of the hyposulphite solution. Then transfer to a large shallow pan, in which may be placed as many prints as it will hold without laying thickly on each other. Leave them in for about a quarter of an hour, with occasional movement, and then pour off quite dry. This point is important, as the chemist well knows—viz., when washing a deposit to drain off the last portion of liquid completely before adding fresh water. Repeat this process of changing at least five or six times, or even more, according to the bulk of water, number of prints, and degree of attention paid to them. Lastly, place them together in a larger vessel of water, and allow to soak for several hours, stirring occasionally. Then blot off with filtering paper, and hang up to dry.

Drying.—The fluid which drains from the edge of a washed print may be tested for hyposulphite of soda, by touching with a rod dipped in solution of protonitrate of mercury; a black colour, which is sulphuret of mercury, indicates the presence of hyposulphite. The common plan of tasting the lower corner for the sweet hyposulphite of soda and silver is now thought by the writer to be insufficient.

When the print is nearly dry, it is recommended by some to place it between two layers of blotting-paper, and press with a moderately hot iron. This appears to darken the tint slightly if produced in a feeble colouring bath, but when the bath is active it causes but little appreciable change.

Albumen proofs when dry are sufficiently bright without further treatment; but in the case of plain paper, salted simply, or with serum of milk, the effect is improved by laying the print face downwards upon a square of plate glass and rubbing the back with an agate burnisher, sold at the artist-colourman's. This hardens the grain of the paper and brings out the details of the picture.

Mounting.—In mounting the proofs, be careful not to employ sour paste, which may possibly injure the tint, and keep them in a place free from damp and mould. Thick gum-water answers very well as a cement, or gelatine dissolved in hot water. Some use caoutchouc dissolved in mineral naphtha, which has the advantage of drying speedily, and does not make the card board cockle up.

Mr. Sutton's Process for Toning Positives.—This process was communicated to the Photographic Journal in the month of March, 1856. It is somewhat more troublesome than the plans ordinarily followed, but possesses advantages which will presently be enumerated. The description may be divided into preparation of the toning bath and manipulatory details:—

"*Preparation of the Toning Bath.*—Dissolve chloride of gold one grain, and hyposulphite of soda three grains, each in two ounces of distilled water; then mix quickly by pouring the former solution into the latter, and add five minims hydrochloric acid. If the chloride of gold is neutral the liquid will have a red tinge, but if acid, then the solution is colourless.

"In place of making an extemporaneous hyposulphite of gold by mixing the chloride with hyposulphite of soda, Mr. Sutton employs the crystallized sel d'or, half a grain to the ounce of water, acidified as before, but the objection to the use of this salt is its expense, and also the difficulty of obtaining it in a pure form; some samples containing no more than five per cent. of gold.

"The quantity of solution given in the formula is sufficient to tone more than a dozen prints of five inches by four; and, therefore, as chloride of gold is sold at twopence per grain, this process cannot be objected to on the score of economy.

"The bath is most active when first prepared, but it will keep for some time, provided the prints be properly freed from soluble nitrate of silver.

"The paper may be prepared by either of the three formulæ given by Mr. Hardwich, according to the tint desired. The printing is not carried quite to the usual intensity, as the gold bath dissolves the half-tones scarcely or not at all.

"On coming from the frame the prints are washed thoroughly in common water until it ceases to become milky; which will not happen until the greater part of the nitrate of silver is removed. The washing must be conducted in a dark place, but it is not necessary to hurry it; the proofs may be thrown into a pan of water covered with a cloth, and allowed to remain until required for tinting.

"A trace of free nitrate of silver usually escapes the washing unless it has been done very carefully and with hot water. This would cause a yellow deposit (probably hyposulphite of silver or a salt of a similar kind, mixed with metallic gold) on the print, and also in the toning bath. It must, therefore, be removed either by adding a little salt to the water during the last washings, or better still by means of a dilute solution of ammonia.

"To prepare this alkaline bath, take liquor ammoniæ one drachm, common water one pint. The exact quantity is not material; if the liquid smells of ammonia it will be sufficient.

"Place the washed prints in this bath, two or three at a time and allow to remain until the evanescent purple tint begins to give place to a red tone. The action must be watched, because if the ammonia bath is strong the proof soon becomes pale and red, and when that is the case you lose a little brilliancy in the after tinting. Albuminized and English papers, from their dense structure, require a longer time in the ammonia than porous papers simply sorted.

"With ammonio-nitrate prints this bath may be omitted; the proofs being transferred to the toning solution immediately after washing.

"As chloride of silver is comparatively insensitive to light, when the excess of nitrate is washed away, it is not necessary to darken the room; but a bright light proceeding from an open door or window should be avoided.

"The ammonia having done its work, soak the prints again for a few minutes or longer in common water to wash out the alkali. Then place them in the toning bath of gold and acid; do not put in too many at once, and move them about occasionally to prevent spots of an imperfect action at the point where the sheets touch each other.

"The foreign papers, plain salted, colour rapidly in two or three minutes. English papers require from five to ten minutes; albuminized, ten minutes to a quarter of an hour.

"By removing the print before the deposit of gold has fully taken place, you obtain a dark red-purple tint, and by a longer action a violet purple approaching to black. When this tone is reached a continuance of the action produces but little change; there is a slight diminution of brightness, but not that yellow tint so commonly seen with old and acid hypo baths.

"The toning being completed, the prints are again placed in water (the same used for washing out the ammonia does very well) to remove the greater part of the acid. This washing must not be continued longer than five or ten minutes, or there will be a danger of decomposition of a salt of silver, producing a yellowness of the whites; this, however, ought never to happen with proper precautions.

"Lastly, the proofs are fixed in a new solution of hyposulphite of soda, one part to four of water. This bath alters the tone slightly. In the case of ammonio-nitrate prints the purple black passes by degrees to a black almost pure.

"In order that the fixing may be properly performed, the time of immersion should not be less than ten minutes with a porous paper, plain salted, or fifteen to twenty minutes in the case of an English or albuminized paper.

"It will sometimes happen in this process, from the toning bath having but little solvent action on the light shades, that the prints, after being washed and dried, appear too dark; this may be remedied by laying them for a few minutes in a very dilute solution of chloride of gold, and washing for an additional quarter of an hour. Five or six drops of solution of chloride to a few ounces of water, not enough to change the colour of the liquid, will suffice.

"*Advantages of Toning by this Process.*—1. The toning solution can be prepared in a few minutes with its full amount of efficacy, and will yield a similar tint any number of times successively. On the other hand, fixing and toning baths of hypo and gold, by the continued immersion of prints, alter in composition, and in their action upon the print, almost daily.

"2. The free nitrate of silver is removed from the print before it enters the fixing bath; hence the purity of the whites is very perfectly preserved.

"3. Bronzing of the deep shadows of the print is removed very perfectly.

"4. Overprinting is scarcely or not at all required.

"5. A pure black and white tint can be obtained with certainty, if the negative is sufficiently intense, by printing upon plain salted paper or ammonio-nitrate paper."

Positive Printing by the Negative Process.—The negative process for printing positivess will be found useful in the dull winter months, and at other times when the light is too weak to act directly upon chloride of silver:—

"A very good iodized paper for illustrating the development of a latent image may be made as follows:—Take of

Iodide of potassium	10 grains.
Water	1 ounce.

Float the paper on this solution in the ordinary manner, and hang up to dry; then by yellow light render it sensitive upon a bath of the following strength:—

Nitrate of silver	30 grains.
Acetic acid (glacial)	30 minims.
Distilled water	1 ounce.

Three minutes' contact will be sufficient; after which dry thoroughly, carefully excluding all rays of white light.

"Develop with a saturated solution of gallic acid, which may conveniently be applied by the ingenious contrivance of Mr. Buckle, already described. Ordinary camel's-hair brushes are quickly destroyed by the mixture of gallic acid and nitrate of silver, unless kept scrupulously clean.

"Gallic acid is soluble in about one hundred parts of cold water; therefore, to prepare a saturated solution, add five grains to each ounce, and apply a gentle heat. The aqueous solution decomposes, and becomes mouldy by keeping; this may be partly obviated by adding acetic acid (a drachm of the glacial acid to twelve ounces of the solution), or by a drop or two of oil of cloves.

"*Sir W. Newton's Process for Printing Positives.*—Bromide of potassium or calcium is used in place of iodide of potassium, as yielding a better tint and more purity of the white parts of the picture. Take of

Bromide of calcium	10 grains.
Gallic acid	5 grains.
Water	10 ounces.

"Cut up a bit of camphor of the size of a nut into small pieces, and digest it with the water for twelve hours, to obtain a saturated solution. Then add two or three lumps of white sugar, the gallic acid, and the bromide, as advised in the formula.

"Apply the solution to the paper by brushing, and when dry, excite with the following bath:—

Nitrate of silver	12 grains.
Acetic acid (glacial) . . : .	20 minims.
Distilled water	1 ounce.

This solution must be applied by brushing, since, in adopting the ordinary plan of floating, the bath would be discoloured by the gallic acid in the paper.

"The following directions are given for the exposure and development of the picture:—Expose to the light (not sun) in the printing frame until a slight change takes place in the colour of the margin—from half a minute upwards, according to the light. A very little experience will, however, regulate this point. After which develop by immersion in gallic acid (of course in a yellow light) ten grains to ten ounces of distilled water, in a flat dish, as many as ten or a dozen at a time. During the process of developing, a small quantity of aceto-nitrate of silver may be added, occasionally gently agitating at the same time.

"Unless Canson's paper be albuminized, it will not answer the object; if, however, it be albuminized, it should be floated over the different solutions. I do not like the French paper, but much prefer Whatman's."

Mr. Sutton's Negative Process.—The paper is prepared with serum of milk, with or without bromide of potassium. The serum is used to impart a warmer tone to the reduced silver than that obtained on plain paper.

"In the preparation of serum of milk, Mr. Sutton advises to separate the caseine by rennet (previously washed to remove salt), in preference to using acetic acid. The serum must be filtered very carefully. The papers are immersed several at a time, and subsequently hung up to dry. The addition of bromide of potassium, five grains, to each ounce of serum, greatly increases the sensitiveness of the paper.

"Aceto-nitrate of silver is used in sensitizing, prepared by the following formula:—

Nitrate of silver . . .	20 to 30 grains.
Acetic acid (glacial)	30 minims.
Distilled water	1 ounce.

Immerse the papers, taking care that both sides are evenly wetted, and allow to remain three minutes; then hang up to dry in a perfectly dark place.

"The development is conducted by immersion in solution of gallic acid, either saturated, or if that should act too quickly, as it will sometimes do in hot weather, the same diluted with an equal bulk of water. This part of the process occupies about five minutes.

"*Remarks on Printing by the Negative Process.*—Mr. Hardwich advises the amateur to master the manipulation of the ordinary positive process before trying that by development. Perfect cleanliness is most essential, and the solutions should all be filtered with care to free them from fine particles in suspension, which would cause spots.

"White light must be excluded with all the precautions exercised in the case of collodion negatives.

"The exposure to light is conducted in the ordinary printing-frame; it extends from a few seconds upwards. On removing the negative a very faint image is seen, which develops rapidly when the gallic acid is applied.

"The development being completed, the prints are well washed and fixed in hyposulphite of soda, one part to four of water. The tint is improved by adding a little nitrate of silver (a few drops of the exciting bath) to the gallic acid towards the end of the process; but a better plan is to tone the prints in the gold bath, described at page 245, before fixing.

"In that case, after developing, they must be well washed, then placed in salt and water, or in dilute ammonia, and afterwards toned and fixed in the manner already fully described.

"The appearance of prints taken by the negative process is artistic and good; but it is difficult to get the same elaborate definition and clearness of shadow, as by the ordinary positive process upon chloride of silver."

On the Fading of Positive Proofs.—The fading of paper positives has long been a source of annoyance to photographers; a gradual loss of brilliancy and a yellow tint is seen to commence at the margins and half-shadows of the print, and to extend by degrees over the whole surface.

"This matter has of late become of such importance that the council of the Photographic Society decided a few months since upon appointing a committee, of which the writer has the honour of being a member, to examine and report upon it.

"The experiments required, in order to be decisive, must necessarily extend over a long period of time, and it will be many months before the results can be fully known. The proofs which fade most frequently are those which have been fixed and also toned. It is this part of the process, so necessary to the artistic effect, which increases the danger.

"If a positive picture, as taken from the frame, be immersed in a solution of old hyposulphite, that is, hyposulphite associated with a compound containing loosely combined sulphur—and when properly tinted, be removed and hung up to dry without any previous washing, it soon turns yellow and becomes altogether pale and faint. Some have thought that the change is caused by the black sulphuret of silver absorbing oxygen and being converted into sulphate of silver; but this cannot be, because a solution of an alkaline sulphuret, which blackens sulphate of silver, has no effect in restoring the original colour of this yellow substance.

"It appears more probable that the yellow fading is due to an excess of sulphuration, or of sulphuration and oxidation combined.

"The action of sulphuretted hydrogen gas or an alkaline sulphuret upon darkened chloride of silver has been studied by more than one observer. It first blackens the brown tone and then changes it to a greenish-yellow. This indeed is the same effect as that produced by the ordinary sulphuretted hypo toning bath, which always causes yellowness when too long continued."

If we then bear the fact in mind that an excess of sulphur destroys the print, it will be easy to understand some of the more obvious causes of fading. Some of these causes, in an abbreviated form, I give from Mr. Hardwich's "Chemistry of Photography."

Imperfect Washing.—This, he says, is the most important of all, and the most frequent. If hyposulphite of soda, even in minute quantity, be allowed to remain in the print it will certainly cause fading. In that case you have sulphur liberated by a slow process of spontaneous decomposition; and the sulphur acting, alone or in conjunction with oxygen, on the already sulphuretted print, turns it yellow.

Dilute fixing and toning baths are often preferred from their yielding very brilliant tints; but it cannot be shown that their employment is unscientific and wrong. Upon the surface of the print, as it comes from the frame, there is much free nitrate of silver, which, when immersed in the fixing bath, forms hyposulphite of silver, a spontaneously decomposing salt. This should be dissolved immediately by an excess of hyposulphite of soda, if it is to be rendered permanent. Therefore if a bath is prepared so dilute as to contain only one part of hypo to about six or eight parts of water, the strength of the solution being insufficient, a shade of brown may be observed passing over the surface of the print on its first immersion, and a large deposit of sulphuret of silver soon forms as the result of this decomposition. On the other hand, with a strong hyposulphite bath there is little or no discolouration and the black deposit is absent.

The most scientific mode of printing is, no doubt, that in which the nitrate of silver is washed out of the proof immediately on its removal from the frame. This point being attended to, a picture is obtained with the lights pure and free from any salt of silver, which may be proved by subsequent immersion in hydrosulphate of ammonia, whereas in the ordinary process there must be decomposition more or less at every part of the surface, as shown by the rapid change of properties which the bath of new hyposulphite experiences.

On Mounting Proofs.—All cements that are of an acid nature or liable to spontaneous decomposition should be avoided. Sour and mouldy paste is very objectionable, but even this is better than paste containing corrosive sublimate, and sold as "everlasting."

Light and Moisture as Causes of Fading.—The print should certainly be kept in a dry place, free from damp and mouldiness; on this all are agreed. The exact action of light, however, upon paper positives is not so well known, although it is generally considered that they retain their brilliancy more perfectly when exposure to bright light is avoided. This point is one to which the attention of photographers is especially directed.

Toning without Gold.—It has been said that the prints toned in hyposulphite of soda containing no gold invariably fade; but such a statement cannot be substantiated, since many are in the possession of photographers of that kind which have stood for years. The coloured surface of a merely sulphuretted print is easily susceptible of injury, since the simple pressure of the warm hand (leaving behind probably a little acid) will often produce a yellow mark. The employment of gold salts in photographic printing, however, by causing a deposit of metallic gold, increases the chance of permanency under unfavourable conditions.

The process of M. Le Grey with chloride of gold used alone, and that of Mr. Sutton with the hyposulphite of gold and hydrochloric acid, are both likely, on theoretical grounds, to give great permanency. The toning bath in both cases is acid to litmus-paper, but the acidity is different to that generated by old hyposulphite of soda, and does not tend to produce yellowness of the proof.

Negative Printing as Obviating Fading.—If the print be simply developed by gallic acid, and afterwards fixed in solution of hyposulphite of soda newly made, it would then be in the condition of an ordinary calotype negative, which the experience of many years has shown to be permanent. But it is difficult to obtain brilliancy of tone by this mode, and if a gold bath be used to darken the shadows, the case is altered. A developed print, toned and fixed, may be more indestructible than one obtained by the ordinary process.

" The following is a simple plan by which the permanency of a positive proof may often be tested. Lay the washed print, whilst still damp, upon a clean sheet of glass, and allow water to drip slowly upon it for twenty-four hours; if it retains its brilliancy unimpaired at the end of that time, it may be considered permanent. A convenient plan is to fill a small basin with spring water, and to hang a piece of stout cotton over the side; this acts as a syphon, and keeps up a constant dropping. The action of the air and water together will produce fading and yellowness, if the picture is not properly washed.

On Printing Enlarged and Reduced Positives.—If a collodion negative be placed at a certain distance in front of a camera, and, by a tube of black cloth or some similar contrivance, the light be admitted into the dark chamber only through the negative, an image will be formed upon the ground glass which is reduced in its dimensions; but if the negative be advanced nearer, the image will increase in size until it becomes first equal to, and then larger than, the original negative. At the same time, it is formed at a point more and more distant from the lens; that is, it recedes as the negative is brought nearer.

Again, if a negative portrait of a sitter be placed in the camera slide, and the instrument being carried into a dark room, a hole be cut in the window-shutter so as to admit light through the negative, the luminous rays, after refraction by the lens, will form an image of the exact size of life upon a white screen placed in the position originally occupied by the sitter. These two planes in fact, that of the object and of the image, are strictly conjugate foci, and, as regards the result, it is immaterial from which of the two, anterior or posterior, the rays of light proceed.

Therefore, in order to obtain a reduced or enlarged copy of a negative, it is necessary only to form an image of the size required, and to project the image upon a sensitive surface either of collodion or paper.

A good arrangement for this purpose may be made by taking an ordinary portrait camera, and prolonging it in front, by a deal box blackened inside and with a double body to admit of being lengthened out as required, or, more simply, by a framework of wood covered in with black cloth; a groove in front carries the negative, or receives the slide containing the sensitive layer, as the case may be.

In reducing photographs, the negative is placed in front of the lens, in the position ordinarily occupied by the object, but in making an enlarged copy it must be fixed behind the lens, or, which is equivalent, the lens must be turned round so that the rays of light, transmitted by the negative, enter the back glass of the combination and pass out at the front. Mr. Shadbolt, who has given attention to the subject, shows the necessity of attending to this point, in order to avoid indistinctness of image from spherical aberration.

A portrait combination of lenses of two and a half or three and a quarter inches is the best form to use, and the actinic and luminous foci should accurately correspond, as any difference between them would be increased by enlarging. A stop of an inch or an inch and a half aperture placed between the lenses obviates to some extent the loss of sharp outline usually following enlargement of the image.

The light may be admitted through the negative by pointing the camera towards the sky; or direct sunlight may be used, thrown upon the negative by a plane reflector. A common swing looking-glass, if clear and free from specks, does very well; it should be so placed that the centre on which it turns, is on a level with the axis of the lens.

The best negatives for printing enlarged positives are those which are distinct and clear; and it is important to use a small negative, taken at a considerable distance, which strains the lens less, and gives a better result in every way than one of larger size. In printing by a two and a quarter lens, for instance, prepare the negative upon a plate about two inches square and afterwards enlarge it four diameters.

Paper containing chloride of silver is not sufficiently sensitive to receive the image, and therefore the print must be formed upon collodion, or on iodized paper developed by gallic acid.

The exposure required will vary greatly, not only with the intensity of the light and the sensibility of the surface used, but also with the degree of reduction or enlargement of the image.

In printing upon collodion, the resulting picture is positive by transmitted light; it should be backed up with white varnish, and then becomes positive by reflected light. The tone of the blacks is improved by treating the plate first with bichloride of mercury, and then with ammonia.

ON THE DAGUERREOTYPE.

I have already stated, in the brief history of this discovery, the circumstances under which it originated and acquired its name from one of the original discoverers. The Daguerreotype picture is taken on a copper plate, with a silvered surface. We have seen that the paper process, and afterwards the glass plate coated with various organic substances, have gradually superseded the silvered plate, especially in this country; but as a branch of Photographic Art it forms an important chapter.

The beautiful process by which the Daguerreotype picture is obtained, was published to the world in July, 1839, after the French government of the day had rewarded M. Daguerre with a pension of 6000 francs, and M. Isidore Niepce, the son of his colleague in the discovery, with another of 4000, with a half in reversion to their widows—a liberal endowment, worthy of imitation on the part of the British government on similar occasions. The process divides itself naturally into six operations, which we shall describe in the following order:—

Preparing the Plates.—The object in this operation is to obtain a perfectly pure and polished surface of silver; it is therefore of the greatest importance that the articles used, in the latter part of the process, should be perfectly free from grease, or any other article of a fixed oily nature. Many ways and substances have been proposed for these purposes; but the following methods I have generally found produce the best results, they are most simple in their details. The materials required are calcined tripoli, prepared lampblack, rouge, and olive oil.

There are several varieties of these plates, under the names of English and French, manufactured, as the names import, in those countries. The plates manufactured in England are generally thicker and have more silver on them than the foreign, from which circumstance they receive a finer surface, and are more useful for beginners, as they will bear cleaning for a great number of times. The French plates, being cheaper than the English, can be employed when practice has enabled the operator to be nearly certain of his results. They are usually marked 1·40 and 1·30, indicating the thickness of silver on them, and consequently their quality; those marked 1·40 will scarcely admit of being used a second time, but the other may, perhaps, with care, be polished three or four times without removing the silver altogether.

In the preparation of plates, hammering seems to be absolutely necessary, binding together, as it were, the materials of the metal; but to be effective it requires to be done with skill, intelligence, and much care. The anvil, as well as the hammer, requires to be very slightly rounded, so that each stroke produces a smooth and even surface, without cavities. It is also necessary to have near the anvil a pair of bellows, which the operator can move with his foot, and from which a blast of wind is thrown upon the surface of the plate, which has the effect of removing any grains of the metal, or other corpuscles raised either by action of the hammer or of the atmosphere. The hammering, when accomplished in this manner with a deposit of silver sufficiently thick, renders the plate capable of the highest polish.

Coating the Plates.—In reference to the Daguerreotype plates of commerce, and the necessity of the silver of the plate being chemically pure, the following experiment of M. le Baron Gros, is conclusive. Having procured a new plate, double silvered in the ordinary manner, he plunged one half of the plate into a galvanic trough, and gave it a fresh coating of pure silver, submitting it afterwards to the usual preparations. The image obtained on the plate presented the following characteristics:—In the part of the plate which was left in its original state, the image was scarcely visible, while that portion which had received the galvanic deposit, presented a fully developed picture.

This experiment of the Baron Gros was highly satisfactory to the Daguerreotypist, inasmuch as it not only teaches him how to render an imperfect plate useful, but how he may use any old plates. It is not necessary to give the reader all the details of the process here, seeing he can refer to Mr. Gore's treatise on Electro-deposition; but I shall briefly detail the process adopted by the Baron, referring to Mr. Gore's treatise for the principles.

If the plate is a new one, which it is wished to renew or increase the silvering, the process commences by drilling small holes in two of the corners of the plate, for the purpose of suspending it in the solution; the back of the plate is now to be varnished all over with a non-conducting varnish, either copal or sealing-wax dissolved in naphtha will serve the purpose.

The form of battery now most universally employed for electrotype and other galvanic purposes is Smee's (Fig. 75). It consists of a piece of platinized silver, A, on the top of which is fixed a beam of wood, B, to prevent contact with the silver. The binding screw, C, is soldered on to the silver plate, to connect it with any desired object by means of the copper wire, C. A plate of amalgamated zinc, D, varying with the fancy of the operator from one half to the entire width of the silver, is placed on each side of the wood. This is set into a glass vessel, P, the extreme ends of the wood resting upon its edge, on which the acid with which it is charged has no effect. The jar is charged with sulphuric acid (common oil of vitriol), diluted in eight parts its bulk of water. The zinc plates of the battery have been amalgamated with quicksilver, and when the battery is set into the jar of acid, there should be no action perceived upon them when the poles, F, G, are not in contact. Should any action be perceived, it indicates imperfect amalgamation; this can be easily remedied by pouring a little mercury upon them immediately after removing them from the acid, taking care to get none upon the centre plate A.

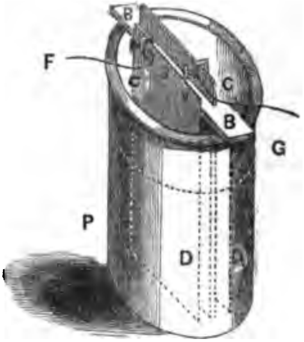


Fig. 75.

Directions for Use.—A sheet of silver must be attached to the wire connected with the centre plate, A, of the battery, and placed in the silver solution—prepared as directed below. The plate to be silvered is first cleaned with diluted sulphuric acid, and then attached to the wire, G, proceeding from the zinc plates, D, D, and placed in the silver solution, opposite the silver plate attached to the pole, F, and about half an inch from it. A slight effervescence will now be perceived from the battery, and the silver will be déposited upon the Daguerreotype plate, while at the same time a portion of the silver plate is dissolved.

To Prepare the Solution of Silver.—Dissolve one ounce of chloride of silver in a solution of two ounces of cyanide of potassium, previously dissolved in one quart of water. The oxide of silver may be used instead of the chloride. This solution is put into a tumbler or other vessel.

Polishing the Plates.—To polish Daguerreotype plates so as to make them perfect, requires two distinct conditions—one mechanical, the other chemical: the perfecting of the metallic surface, and the exquisite cleanliness requisite to insure the purity of the silver surface which is to receive the photographic image. The importance of chemical purity has already been shown.

Many fanciful theories were formed on the subject of preparing the surface of the plate for receiving the Daguerreotype. MM. Belfield and Foucault attributed their own success to a coating of organic matter, which diffused itself over the plate; and M. Daguerre himself fancied he had discovered a galvanic action in a combination of three or four metals, which favourably disposed the plate to receive the coating of iodide of silver and bromine, but experience soon demonstrated the inefficacy of his fancied discovery. Let us then throw aside all these theories. Every mode of polishing, whatever it may be, that insures to the plate a perfectly smooth surface, and great chemical purity, may in practice be adopted without inconvenience. Among the methods of polishing which have received the sanction of experience, we shall describe those only which are simple and efficacious.

The Polishing Table.—Formerly, when about to polish, following the instructions of M. Daguerre, it was thought sufficient to place the plate on several sheets of paper, which were renewed as soon as soiled, and kept in its place with the fingers of the left hand, while the right directed the pledget of cotton. These means were soon found insufficient, and a small polishing board, fixed on a table by means of a small press, was devised. The plate was fixed on this board by means of two small copper catches, whose raised extremities were pierced by a small groove, to which the corners of the sheet of the plate were fixed. M. Levret was the first who conceived the happy thought of substituting for the raised edges of the copper catch a small flat metallic button at each corner of the plate. By this contrivance, now generally adopted, no obstacle opposes the action of the pledget of cotton or other polisher used.

Figure 77 represents the polished board under this last form; its surface is of rather smaller dimensions than that of the plate, and it is covered with a piece of thick cloth or flannel fixed to it with strong glue. This precaution is indispensable to insure the perfect contact of the plate with the board. At the corners of the small board four little copper grooves will be observed, B, B, B, B, each surrounded with a small flat button of the same metal. Under each of these is fastened a corner of the plate. Four little bolts, provided with screws and handles, are placed underneath the board, which permit it to be moved backward and forwards, and adjusted according to the will of the operator.

Fig. 76.

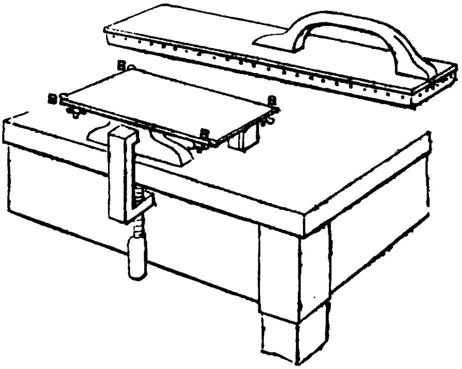


Fig. 77.

The cotton-velvet polishers employed by M. Claudet, and even those of deer-skin since adopted, would quickly be spoiled by the sharp edges of the plate, if care were not taken to turn down the edges in such a manner that the polisher cannot be caught by them. This simple operation is performed with the assistance of a steel burnishing stick. A small board of wood is taken, furnished with a steel ruler, while the outward edge is covered with leather. The plate is disposed upon this board, the silvered face up, so that its edge is in contact with the sharp cutting of the steel ruler. Passing the burnishing stick over it once or twice round the edge of the plate sufficiently for the purpose. This operation is of course repeated all round the plate. The four corners of the plates are now placed, by means of flat pincers, under the four buttons of the polishing board.

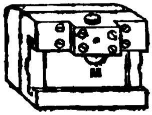


Fig. 78.

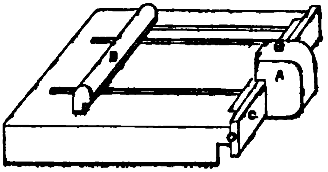


Fig. 79.

Figures 78 and 79 represent a very useful machine for the operation just described; it consists of a wooden frame furnished with a steel ruler. The outside edge of this shelf has a second ruler of iron, or of hard wood, perpendicular to the first, which serves to guide the plane A (Fig. 79). In Fig. 79, the letter B indicates a moveable cheek of wood, which serves to adjust the plate, and prevents it from moving backward while the plane is in action. The use of this plane is easily understood; a small pair of steel nippers in Fig. 78, which cuts at an angle, and which acts concurrently with the steel rule, is fixed on the board, and serves to depress the edge of the plate.

And now let us give our attention to the polishers. Fig. 76 represents one of these; it consists of a small board of soft wood, from twenty to twenty-four inches in length and about six broad, and in thickness about one and a half, furnished with a handle a little resembling that of a joiner's plane. Over this board is stretched, by means of some carpet nails, some thickish material like flannel. Over this again is placed a very fine sheet of pasteboard, and over the whole a piece of white cotton velvet or doeskin, firmly nailed to the edges of the board. Four polishing brushes, two of velvet and two of deer's-skin, stretched tightly over them, are required; and, we need not add, these polishing instruments require extreme cleanliness, and should be carefully put away, each in their separate box, every time after being used.

M. le Baron Gros recommends for the first operations of polishing, small pledgets of his own contrivance, the use of them are both simple and economical. In Fig. 80, is seen the model of one of these pledgets, or dabbers, which may be made in wood. The square part is finished with a thick surface of India-rubber, over which a small square of cotton velvet is arranged, which is renewed whenever it is required. This square of velvet, whose opposite corners press against the contracted parts of the pledget, is kept in its place by the fingers of the operator, the round stuffed part of the pledget being placed in the palm of the hand.

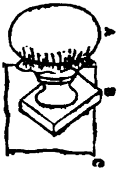


Fig. 80.

After numerous experiments in which nearly all the substances that can be reduced to fine powder, have been successively tried, the greater part of them have been abandoned, and tripoli powder, blacklead, and English rouge are almost exclusively used. It is known that a perfect polish is not easily obtained with pumice-stone and tripoli, for, besides the difficulty of a trick of using the hand that is not easily acquired, these substances, such as we can procure them in commerce, even when washed, are far from being in a state of sufficient purity to produce the required surface on the silvered plate. It is thus necessary to subject these substances to a new washing and decantation. This is performed as follows:—

Into a large decanter or glass jar filled with water, pour a handful of pumice-stone or of tripoli powder; shake the glass well, then let it remain for four or five minutes to settle the pumice stone, and two or three for the tripoli; then by introducing a syphon into the glass, the lower end of which should not be dipped more than half the depth of the liquid, the water containing in suspension the thinnest particles of the pumice-stone, as tripoli is drawn off; when this powder is half dry, it is placed in a porcelain crucible, or if there is no crucible at hand, in the top of an earthen pipkin, and a strong heat applied by means of a spirit lamp. It is not necessary, however, to carry this calcination to a red heat; it is sufficient that the powder is quite free from moisture. With pumice stone or tripoli powder thus prepared, a perfect polish may be obtained; but to give the last touch to the plate, and so burnish it to an intense black, it is necessary that English rouge should be used, and it is well to be very particular as to its quality.

Polishing powders should be shut up in small glass bottles, with a large opening, and the orifice closed with a metallic gauze; thus the inconvenience of soiling the fingers will be avoided. These bottles should be carefully shielded from moisture; and it is best in damp weather to place them near the fire, that the enclosed powders may be well dried.

The plate being fixed to the polishing board, two or three drops of essence of turpentine are poured over it, and a little prepared pumice and tripoli added, with a cotton pledget that need not be new, rub round and round, forming a number of small circles very near but not touching each other, carefully going equally over every part of the surface. After about a minute a black greasy substance will be formed on the silver, of which the largest part must be removed, continuing to rub round with the same cotton. After a time add a small quantity of dry pumice or tripoli to the plate, and with a new pledget rub on, still in a circle, till the surface of the plate takes a vivid brightness. This is the first stage of the work.

Arrived at this point, pour over the plate three or four drops of a mixture of essence of turpentine, and of alcohol in the proportion of one part of alcohol to half of turpentine; to this add a little pumice or tripoli, spreading it lightly over the whole surface of the plate, with the same pledget used in the preceding operation. When this coating of tripoli is spread regularly over the surface let it dry. There will then form upon the plate a thick crust of a dead white colour; in less than a minute the drying is completed; and to finish polishing there is only the coating of tripoli to be removed.

For this purpose a new pledget is taken, and this time the plate is rubbed in a contrary direction; in a very short time the burnishing will be perfect, and the plate ready for iodizing.

The process just described saves much time, and can be applied to all plates, whether they are new or have been previously used. The essence of turpentine having been once employed, it would appear that no trace of old impressions ever reappears on the plate. This remarkable consequence is attributable to a chemical influence, of a particular nature, which the essence exercises upon the coating of silver; and the superiority of the method of Messrs. Belfield and Foucault is attributed to a mechanical action exercised on the metal by the essence of turpentine and other essential oils, which, it seems, have the effect of destroying and completely removing the coating of silver combined with iodine, and producing an entirely new surface.

Another remarkable effect of essence of turpentine is, that plates thus polished can absorb a much larger quantity of accelerating substance without inconvenience. That upon a plate polished in the old manner, for instance, the least excess of bromine betrays itself by a mist more or less thick, which obscures all or part of the image; with the essence, on the contrary, it would require the excess of bromine to be very considerable to cause a cloud on the impression.

M. Claudet's Process.—The Daguerreotype has had no more zealous follower in this country than M. Claudet, and his system comprehends all that has since been introduced as new improvements under the title of American inventions. The principal aim of M. Claudet has been, in preparing his plates, to dispense with the use of cotton, which leaves a slimy coating on the surface. In order to attain this end he submitted them to three successive operations, namely, the softening or polishing preparation, the separating, and the burnishing processes.

In the first operation, the irregularities the hammering has left on the surface, is to be removed; or, in the case of old plates, fresh silvered with chloride of gold. Every trace of former impressions from the surface, whether fixed or not, is to be removed.

The first polishing requires a turning lathe, on the mandrels of which is mounted a disk of wood, varying in size and thickness according to the size of the plate. This disk is to be first covered with a thick woollen or cotton material, and over this fresh covering a piece of white cotton velvet is tightly stretched; this covering must be without roughness or colour, and it should be boiled for an hour in pure water and then dried. A few drops of olive oil are now poured over the plate, which is then sprinkled over with a little powdered pumice-stone or tripoli powder, carefully prepared, washed, calcined, and dried. The silvered surface of the plate is now applied to the velvet disk, and kept in this position by means of a wooden block supplied with a coating of India-rubber to soften the pressure of the disk. The turning-lathe is now put in motion, and the velvet-covered disk is made gradually to run over the whole surface of the plate. By a series of eccentric strokes the plate is crossed on every side, and in a very short time the surface of the plate will be brought up perfectly even and softened.

The Separation.—The plates have now to be cleared of the coating of oil adhering to its surface, tarnishing its brightness and rendering it incapable of photogenic action. This point is attained by boiling the plate for about half an hour in a saturated solution of carbonate of soda plunging it afterwards in boiling water, and gradually drying it on a piece of clean calico conveniently stretched for the purpose. The plates are now ready to undergo the last polish.

For the third polishing, another disk is prepared and covered with perfectly clean cotton velvet, and mounted on the lathe; over the face of the disk is sprinkled a small quantity of English rouge, applying it to the silvered surface of the plate also, and in a few turns it will acquire a perfectly burnished surface, presenting an intensely black appearance when exposed to the light at a proper angle. All that now remains to be done is to restore the transverse direction of the polish, which should be perpendicular to the intended image. This is done by means of a polishing brush formed of wood, with a handle capable of being held in the hand, and supplied with two or three thick coverings of cloth, and finally with cotton velvet. A few grains of rouge should be sprinkled over, taking this brush in one hand and holding the plate with the ends of the fingers of the other; rub it quickly, but very lightly, till the polish has taken the required direction. Quick and repeated rubbing of the plate immediately before iodizing has the advantage of rendering it quicker, more sensitive and more equal in its distribution.

The operations just described can only be conveniently executed on a large scale, and the process adopted by M. Claudet is modified by each practitioner, according to his own requirements and means, combining it as much as possible with that of Messrs. Belfield and Foucault.

By using essence of lavender for oil, some Daguerreotypists dispense entirely with the second operation of Claudet, having no occasion in this case to clean the plates; the annoyance caused by the grease mixed with oil being avoided.

With their usual mechanical ingenuity, the Americans have added some excellent improvements to the appliances previously in use for polishing plates. We cannot finish this subject more appropriately than by describing some of the best of these; and first let us describe Davie's improved lathe, a recent and decided improvement for polishing plates (Fig. 81).

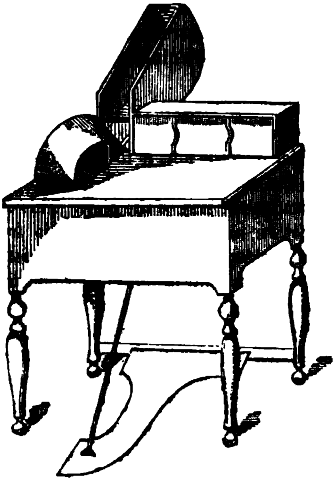


Fig. 81.

There is no part of the Daguerreotype process requiring more thorough manipulation than that of cleaning and polishing the plate, and none wherein the operator has met with less satisfaction. The hand buff, though good, does not give that finely finished surface so desirable in a good picture; and the lathes commonly used are apt, in some instances, to go to the other extreme, and wear the plate bare of silver. Of the many efforts made to improve the buffing-wheel, none have come so near perfection as the above alluded to.

It occupies but little space, and requires slight exertion. The buffer is a cone of cast iron, twenty-three inches in diameter, neatly covered with wood, and forming a free surface six and a half inches wide. This cone runs in a well-adapted case, which stands firmly on four handsomely turned legs, attached to the box by screws. The cone is turned by a treadle with the left foot. Connected with the machine, are four holders for the different sizes of plates. It is certainly a very neat affair, and will undoubtedly do its work quicker and better than anything of the kind now in use.

Plate Blocks and Vices.—There are several kinds of this article in use; I shall describe the two best only:—

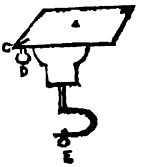


Fig. 82.

Fig. 82 gives an idea of the improvement on the English hand block. The top A is perfectly flat and smooth—a little smaller than the plate, so as to permit the latter to project a very little all round—having at opposite angles C C two clasps, one fixed, the other moveable, but capable of being fastened by the thumb screw D, so as to secure the plate tightly upon the block. This block turns upon a swivel B, which is attached to the table by the screw C. This block is only used for holding the plate while undergoing the first operation in cleaning.

Fig. 83 shows the form of Lewis's newly patented plate vise, which, for durability, simplicity, and utility, is preferable to all others. It consists of a simple platform and arm of cast iron, the former A having a groove D in the centre for fixing the different sizes of plate beds, E, and the latter supporting the levers E F. On this vice, which is secured to a table or bench, the plate receives its finishing polish with rouge, or prepared lampblack. Mr. Lewis gives the following directions for its use:—"As the cam wears, tighten it with the adjusting screw, G, so as to allow the lever, F, to fall back into a horizontal position; the plate being in its place at the time. Oil the wearing parts occasionally." For all ordinary purposes, this vice is sufficient; but in larger establishments, where the lathe is necessary, that above described will be found eminently useful.

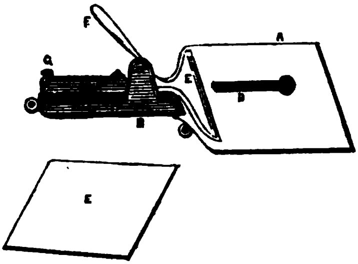


Fig. 83.

Coating Boxes.—The American coating box is also ingenious. The usual form for iodine and bromine boxes is seen at Fig. 84, and consists of a wooden box A, having firmly embedded within it a stout glass jar, the edges of which have been ground. Over this jar is placed the sliding cover B, double the length of the box, one half occupied by a piece of ground-glass, E, tightly pressed upon the glass jar by a spring beneath the cross bar G, and which fits the jar so accurately that it effectually prevents the escape of the vapour of the iodine, bromine, or other accelerating liquid contained therein. The other half of the lid is cut through, shoulders being left at the four angles for the different sizes of frames, designed to receive the plate while undergoing the coating process. When the plate is put into the frame, the cover B is shoved under the second lid H, and exposed to the vapour; when coated to the proper degree, it resumes its former position, and the plate is placed in the holder of the camera box. To test the tightness of the box, light a piece of paper, put it into the jar and cover it with the sliding lid. The burning paper expels the air from the jar, and if it be perfectly tight you may raise the whole box by the lid.

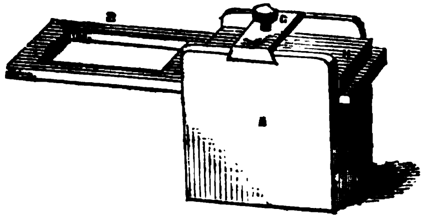


Fig. 84.

Still.—Daguerreotypists should always use distilled water for solutions and washing the plates. For the purpose of distilling water, the apparatus represented at Fig. 85 is both convenient and economical.

It may be either wholly of good stout tin or of sheet iron tinned on the inside, and may be used over a common fire or on a stove. A is the body, which may be made to hold from one to four gallons of water, which is introduced at the opening B, which is then stopped by a cork. The tube D connects the neck F of the still with the worm tub or refrigerator, C, which is kept filled with *cold* water by means of the funnel, and drawn off, as fast as it becomes warm, by the cock F. The distilled water is condensed in the worm, and passes off at the cock G, under which a bottle or other vessel should be placed to receive it. The different joints are rendered tight by luting, or in its absence some stiff paste, spread upon a piece of linen and wrapped around them, will answer very well; an addition of sealing-wax over all will make them doubly secure.

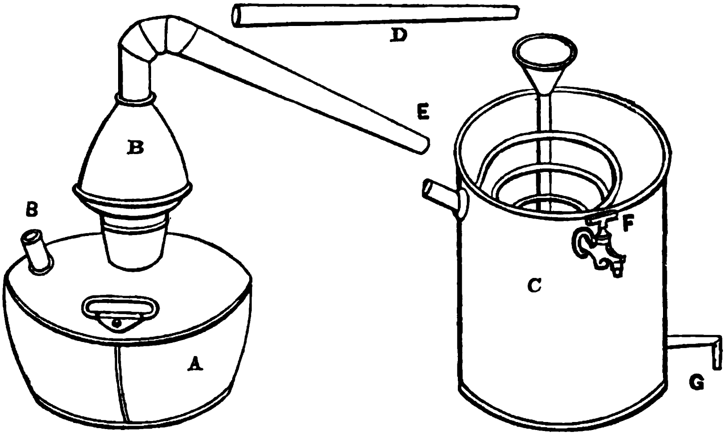


Fig 85.

Preparing Materials.—In whatever manner the materials are to be used, whether by the hand or the lathe, it is essential that they be properly prepared for the purpose. The tripoli requires to be reduced to a perfectly impalpable powder by calcination, and perfectly free from large particles capable of scratching the surface of the plate, and kept for use in a metal or wooden box or bottle contrived for the purpose.

Prepared lampblack is made by burning it to a red heat in a crucible till vapour ceases to arise from it, when the crucible is removed from the fire closely covered up, and suffered to cool. It is then reduced to a fine powder in a mortar, and kept apart in another similar box or bottle.

The rouge requires to be the finest washed that can be procured, and should also be kept in a separate box or bottle. The following mode of using these, as practised in an establishment where a great number of plates are required, is probably as effective as the more elaborate processes described:—"In this establishment there is a lathe, to the head of which can be adapted, by means of the proper screws, a series of circular buffs, the usual number being three. These buffs consist of circular disks of wood, one side of which is covered with a fold or two of unbleached cotton velvet. The buff No. 1 is prepared with olive oil and tripoli; No. 2 with tripoli alone; and No. 3 with lampblack and a small quantity of rouge, or lampblack alone. The plate to be polished is placed in a shallow cavity on the surface of a flat piece of metal, having a projecting tube at its back, and into which is placed a circular iron rod, mounted with a wooden handle, for the purpose of pressing this metal-holder and its contained plate against the circular buff.

The method of proceeding is as follows:—Screw on the buff No. 1, adding, if necessary, some fresh tripoli and oil, and place the lathe-rest about three inches from its surface; the plate is now pressed lightly against the buff, a short distance from its centre, supporting the iron pivot against the rest. The lathe being put in motion by

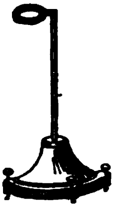


Fig. 86.

the foot, causes the plate to revolve very rapidly over the buff, and very quickly removes from it any former picture, scratch, or tarnish. The plate and its holder should now be lightly wiped with a portion of cotton wool, to remove as much as possible of the superfluous oil, &c. The buff No. 2 is now to be substituted for the oil buff, and the plate again applied in the way just described, till all appearance of oil is removed, and the plate appears equally polished. The plate is now laid, silver side upwards, on a stand, similar to the one here represented (Fig. 86), and the flame of a spirit lamp applied underneath till a slight smoke appears to rise from it, and its surface assumes a slight white tint; by this process the remaining traces of oil are burnt away, and the plate is ready to receive its final polish by means of the buff No. 3.

When the plate is properly polished, its surface should look quite black and free from scratches when viewed in a particular light. If this is not the case, it must be applied some time longer to the buff No. 3 till that result is produced.

The other method of polishing where a lathe cannot be obtained, or would not be admissible on account of its cumbrous nature, consists in employing a series of cotton-velvet buffs, varying in size from three inches by twelve inches to nine inches by eighteen, according to the size of the plates. The least number required is four; the first buff is prepared with tripoli and oil, the second and third with tripoli alone, and the fourth with prepared lampblack and a very small quantity of rouge; they must be kept separate from each other, and each carefully reserved for its own particular use. The method of proceeding is to lay the plate face downwards, upon the oil buff No. 1, and then, by means of a similar plateholder to that employed for the lathe, or else one made of wood of the form represented in Fig. 87, the plane surface of which is rendered adhesive by some prepared India-rubber, the plate is briskly moved over its surface with a very slight pressure for the space of a minute or so; it is then cleared from adhering oil, &c., with some cotton wool, and rubbed lightly first on No. 2 buff, and afterwards on No. 3, adding some fresh dry tripoli as required. The plate is now heated with a spirit-lamp, as before described, and finished on the buff No. 4.

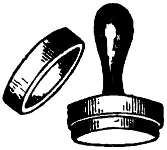


Fig. 87.

If the plate to be polished be very free from scratches, and has not been subjected to the setting process with salt of gold, the use of the oil buff may be dispensed with, and those prepared with tripoli and lampblack alone used.

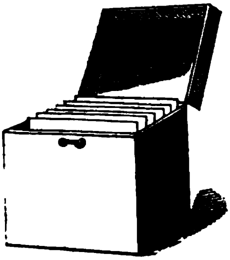


Fig. 88.

The following are the most important precautions to be observed to insure the proper result in the foregoing processes. The buffs and polishing materials should be carefully preserved from dust, dirt, and damp; the former of these is easily accomplished by keeping each separate buff in its own case, which may be made either of wood or parchment, and the latter by keeping them in some dry place. If there should be any doubt relative to the buffs being perfectly dry, it will be advisable to place them, well protected from dust, before a fire, a short time previous to using.

When the plate is polished by either of the processes described it may be protected from injury in a wooden or metal box, similar to the one represented in Fig. 86. When the plate is about to be used, it should receive a final polish, and have its grain laid in a particular direction, by means of a buff, either covered with cotton velvet, or a piece of smooth, soft doeskin, of the shape here represented (Fig. 89).

Fig. 89.

The plate, if a small one, can be supported on the ends of the fingers of the left hand, using the buff with the right; if the plate be too large or thin to be supported on the fingers, any convenient form of plateholder can be employed, taking care that it is perfectly free from dust or grease. The buff should be briskly rubbed over the plate with a slight degree of pressure for a few seconds, or till all the fine lines on the surface of the plate appear in one uniform direction, bearing in mind that for portraits the lines should not be in the direction of the face, but across it; and for views, in the direction of the view. The plate is now ready, and should immediately be subjected to the next operation, which is—

Applying the Sensitive Coating.—The simplest form of apparatus necessary for this purpose consists of two porcelain or glass pans, ground on the edges and furnished with plate-glass covers, and a series of wooden or metal frames of the size of the plate to be prepared; one of these pans is for holding the iodine, and the other the accelerating material. The plate to be prepared is placed in its proper frame, and substituted for the plate-glass cover of either pan, as may be required; the progress of the preparation being observed from time to time by the tint of colour produced on the plate when removed for an instant, and viewed at such an angle that the light transmitted through a sheet of white paper held before the plate may be reflected to the eye. When the proper colour is obtained, the plate is exposed for an instant or two longer, to remove any effect of the light, and then rapidly placed in the camera frame; the glass cover is now replaced.

In consequence of being obliged to remove the cover of these pans to observe the colour of the plate, the vapour of iodine, &c., within the pan becomes disturbed, and rarely produces an even coating; this is avoided by using the glass pans of greater depth, and mounted as shown in Fig. 90.

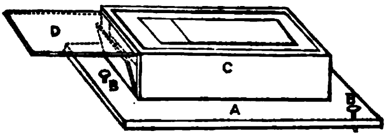


Fig. 90.

The plate to be prepared is placed in the proper opening at the top of the box, and on removing the glass sliding-cover and replacing it again before the plate is removed, a much better result is obtained.

The only form of apparatus that can be relied upon for producing a uniform good result is that shown in Fig. 91, or one constructed on similar principles. It is technically termed a bromine apparatus, and consists of two deep glass pans with polished sides, and mounted in a wooden box, at the back of which are two openings, corresponding to the two pans, over which is fastened a piece of white paper. In the front of the box, and immediately opposite the back openings, are two small doors opening

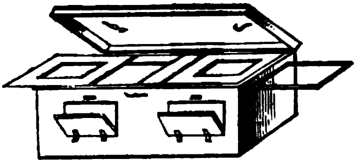


Fig. 91.

outwards, and each lined with a piece of looking-glass. Two glass covers, and a series of wooden frames sliding over them on the top of the box, complete the apparatus. From half to one ounce of pure crystallized iodine is placed at the bottom of one of the pans and the accelerating material in the other, and they are then closed with their respective covers, and the whole apparatus placed before a window with a moderate light. The accelerating material which I have uniformly found produce the best and most certain results is a chloride of bromine, made by mixing one ounce of a satutrated solution of bromine with one drachm of strong hydrochloric acid. This preparation must be kept in a stopped phial. Water is poured into the glass pan of the bromine apparatus to the depth of about half an inch, and sufficient of the chloride of bromine added to bring the whole to the colour of very pale sherry.

The plate to be rendered sensitive to light is placed in its required frame at the top of the bromine apparatus, and immediately over the pan containing the iodine; the plate-glass cover is then removed so as to expose the plate to the vapour of the iodine below; the small mirror is now so adjusted that, by looking into it, the white paper at the back can be seen reflected from the surface of the silver plate, and any change of colour immediately perceived. When the plate has assumed a light straw colour, the cover is to be returned over the iodine, and the slide holding the plate shifted over the pan containing the chloride of bromine; the cover is now to be withdrawn, the mirror adjusted as for the iodine; and the glass cover being removed, the plate is exposed to the vapour till it becomes of a deep yellow colour, when it is returned over the iodine till of a rose tint, and immediately placed in the camera frame. The dilute solution of chloride of bromine will serve to prepare a considerable number of plates; and when it fails to produce its effect, it will always be found the better plan to mix a fresh quantity rather than increasing its strength by the addition of more of the strong solution.

There are a great many preparations of bromine known by the names of eau bromée, bromide of iodine, Hungarian solution, Woolcott's American accelerator, bromide of lime, &c., which are employed by some operators with much success.

When the bromide of iodine, or Hungarian solution, is employed, it should be diluted with four or five times its bulk of water, and the plate, previously iodized to a deep yellow, exposed to it till a deep rose or violet colour. Woolcott's accelerator and bromide of lime both require the same tints as the chloride of bromine before described. The bromide of lime, chloro-bromide of lime, and other dry accelerators of that character, are used in the bromine apparatus, spread evenly over the bottom of one of the pans to the depth of about a quarter of an inch.

Should the plate by accident be left too long over the iodine in the first preparation, and show some indications of a rose tint, it must be brought to a full rose over the accelerator, and then to a blue over the iodine; this will often produce a good result, and save the trouble of re-polishing the plate.

The plate, after being prepared by one or other of the foregoing processes, must be returned to the dark box or camera back till required for the next process, viz.:—

Exposure in the Camera.—The mode in which this is effected must, of course, depend upon the construction of the camera, whether it have a lens, as originally proposed by Daguerre, or a concave mirror or speculum, which is the apparatus patented in this country by Mr. Beard. Both kinds have their advantages. The refracting camera, as recently improved, appears to possess all the capabilities without many of those inconveniences which attend on the manipulation with the reflecting camera, and being withal less expensive, is now the form generally used.

The first thing to be attended to, before introducing the plate, is to place the camera on some firm support, and opposite to the object wished to be copied; after which the focus should be adjusted with the greatest care till a perfectly clear and distinct image of the object is seen on the piece of ground-glass, which should be placed in exactly the same position as the plate is to occupy, taking especial care that the ground side of the glass should correspond to the prepared surface of the plate. When the focus is obtained, the light should be shut off by a brass cap, or other contrivance for that purpose, till the plate is introduced, or the camera may be taken into a dark room, and have the plate put into its place, when it can be brought into the light, having, of course, made those obvious arrangements, that the object and the camera be placed in precisely the same relative positions they occupied when the focus was adjusted.

The camera may then be opened to allow the light to fall on the plate through the lens. The time requisite for it to remain open will depend, in a great measure, upon the season of the year, time of the day, and the brightness or clearness of the atmosphere. The time usually required with a good achromatic and a well-constructed camera varies from one to sixty seconds.

When the camera has been opened a sufficient time, which can only be determined by observation and experiment, close the front aperture, and take it into a dark room, when the picture, which is impressed on the sensitive surface of the plate, is to be made visible by being exposed to the fumes of mercury.

Mercurializing the Plate.—The apparatus required for this operation is called a mercury box, and is shown in the accompanying cut:—

The body, A, is made of wood, and has an iron cup, fixed in the bottom, for holding the mercury, which is heated by a spirit lamp, F; the upper part of the box, A, is grooved, so as to receive the same sliding frame, B, that fits the back of the camera and holds the prepared plate, or else the prepared plate alone; at the front of the box is a small yellow glass window, C, over which slides a shutter, D. When about to be used, pour a small quantity of pure mercury (four to six ounces) into the metal cup at the bottom of the box; the mercury should then be heated by means of a spirit lamp, till the outside of the metal cup can be touched with the finger without much inconvenience. The plate may then be taken from the camera and placed in the mercury a short time, by cautiously applying a lighted taper to the side, and looking through the glass in front, the development of the picture can easily be perceived.

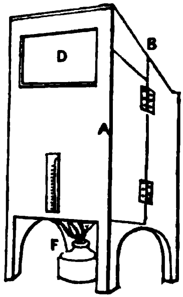


Fig. 92.

If the mercury be made very hot, the picture soon makes its appearance; but, generally speaking, when done too rapidly, the minor details are lost and the plate is apt to become spotty; it is always advisable, where time is not a great object, to do the operation rather slowly than otherwise, as a much clearer and sharper outline of the picture will be obtained by this means than if done rapidly. The usual time required is from five to twenty minutes.

If the mercury box be furnished with a thermometer, which is sometimes the case, the temperature may be kept about 90 degrees.

The mercury should be perfectly dry and free from any particle of oxide, and should be poured into a bottle after each series of experiments. When it loses its brilliancy, it may be purified by filtering through a paper cone, having a very fine opening at the bottom. The mercury box ought also to be carefully dusted out before using.

When the picture has become sufficiently distinct, it should be removed from the mercury box and subjected to the next operation, viz. :—

Removing the Sensitive Coating.—The solution required for this is made by dissolving two ounces of hyposulphate of soda in one pint of water; this solution will serve many times, if it be filtered before using. The solution is placed in some convenient shallow vessel, and the plate quickly immersed in it; the colour will be observed to gradually disappear, and when that is the case it should be placed in a vessel of filtered water, to remove the excess of hyposulphite, and subsequently a small quantity of distilled water poured over its surface.

Fixing the Picture.—The solution of gold which is required for this process is prepared by dissolving 15 gr. of chloride of gold in one pint of water, and adding it little by little, to a mixture of 60 gr. of hyposulphite of soda and eight ounces of water, the whole being well agitated between each addition. The solution, at first slightly yellow, becomes afterwards perfectly limpid. Before the surface of the plate becomes dry, it is to be placed, face upwards, upon the fixing stand, which is so constructed as to preserve it in a perfectly horizontal position by means of levelling screws, and the solution of gold being poured over its surface, until it is perfectly covered, and the flame of a large spirit lamp applied to the under surface, moving it gently beckwards and forwards, that every part may be equally heated, the picture will be seen to brighten, and become in a minute or two of great force. When this effect is produced, the liquid should be thrown off, and the plate instantly dipped into water, washed, and dried. If the plate be a large one, it is most conveniently dried by placing it on a smooth and clean piece of copper or tin plate, and some boiling distilled water poured over its surface, at the same time inclining the plate so that the water may run off from one of its lower corners, and it will in a very short time become perfectly dry.

If the plate be of a small size, it can be conveniently dried over a spirit lamp. It should be held by means of a small pair of pliers, by one of its corners, and some filtered distilled water poured over its surface; by inclining the corner held by the pliers, the greater portion of the liquid will flow to that part, and can be removed by touching it with a piece of rag or blotting-paper; the spirit lamp may then be applied to the upper corner of the plate till it begins to dry, and the flame gradually brought lower down, till the whole surface is finished. Gently blowing downwards on the plate will expedite the process, as well as prevent, in a great measure, the formation of spots.

It sometimes happens that, while the plate is being heated with the solution of gold, a film of silver detaches itself and swims in the liquid, of course destroying part of the picture. This accident is probably owing to the oxidation of the silver while under the influence of too much heat.

The lamp should be removed as soon as the small bubbles of air appear to form on the surface of the metal. When the picture is not perfectly fixed, it is better to make a second trial, rather than run the risk of spoiling a good picture by trying to fix it perfectly the first time.

Colouring Daguerreotypes.—As the objects copied by the Daguerreotype process are only represented in light and shade, not in the colours as they appear in nature, it has been suggested, after the picture has been set, to colour them by hand, similar to a painting; and certainly, when done in an artistic skilful manner, it produces a very pleasing effect. The simplest method is to use dry colours, ground extremely fine, with some dry gum or starch. The picture must be well set with gold, and the colour applied or dusted on with a fine camel's-hair pencil, taking up a very small quantity of colour at a time, removing the superfluous colour by blowing it off with a caoutchouc bottle; when the desired tint is produced, breathing on the plate will cause the colour to adhere. M. Claudet's method is to mix a small quantity of the colour with spirit of wine, applying it to the plate with a camel's-hair pencil, and if not sufficiently dark, some of the dry colour is applied over it, to which it will adhere. As a general rule, the colours should be applied very cautiously, as it is very difficult to remove them when once on the plate. The best colours to be used are carmine, chrome yellow, and ultra-marine, by combining which any desired tint may be obtained.

Daguerre's Improvements.—The Daguerreotype process is, as we have seen, much more complicated in its manipulation, and less satisfactory in its results than either the collodion, wax-paper, or calotype. The preparation of the plates is a mechanical operation, requiring great delicacy in handling, and the application of the sensitizing vapours are processes requiring great care and considerable knowledge of chemical manipulation. The uncertainty of the results, even of the best operators, led M. Daguerre, to return to the subject for the purpose of reviewing his process, which he does in the "Comptes Rendue," of March, 1842. The uncertainty he attributes to two principal causes; first the defective operation of polishing, in consequence of the impossibility of entirely divesting the surface of traces of the liquid, cotton, and other substances, used in the operation, which prevents the iodine from coming into direct contact with the silver, and consequently retards the photogenic action. And, second, in the alterations in the temperature of the air with which the plate is in contact, from the earliest operations to the mercurial bath, in consequence of the colder body of the metal condensing moisture from the surrounding air.

The following process recommended is very simple, and obviates both the inconveniences above mentioned; it frees the silver as much as possible from all dirt or dust, and neutralizes the humidity produced by the elevation of temperature in the mercurial box.

The process consists in covering the plate, after having polished it, with a layer of very pure water, and heating it very strongly over a spirit lamp, pouring off the first layer of water in such a manner that the dust which has been raised, floats away without touching the plate.

It is necessary, in order to accomplish this, to have a frame of iron wire, of the size of the plate, at one of its angles having a handle, and in the middle, on the two opposite sides, two small cramp-irons, to retain the plate when it is inclined. After having placed this frame on a horizontal plane, the plate is placed on it, and is again covered with a layer of very pure water, putting as much as the surface can retain. The bottom of the plate is afterwards very strongly heated, and very small bubbles are formed at the surface. By degrees these bubbles become larger, and finally disappear; the heat must be continued to ebullition, and then the water must be poured off. The operator should commence by placing the lamp under the angle of the frame where the handle is; but before removing the frame, this angle must be very powerfully heated, and then, by gradually moving it by its handle, the water immediately begins to run off. It must be done in such a way that the lamp shall follow, under the plate, the sheet of water in its progress, and it must be only gradually inclined, and just sufficient for the layer of water, in retiring, not to lose in thickness; for if the water were dried up, there would remain small isolated drops, which, not being able to flow off, would leave on the silver the dust which they contain. After that, the plate must not be rubbed; very pure water does not destroy its polish.

This operation should be performed just before iodizing the plate. Whilst it is yet warm, it is placed in the iodising box, and, without allowing it to cool, it is submitted to the vapour of the accelerating substances. Plates thus prepared may be kept one or two days (although the sensibility diminishes a little), provided that several plates be placed opposite to one another, at a very short distance apart, and carefully enveloped to prevent change of air between the plates.

It is one of the most important points to obtain a fine polish on the plate, but the brilliancy often disappears when substances which adhere to the surface of the silver are used, such as the peroxide of iron, which has been very generally made use of for giving the last polish. This substance, indeed, seems to burnish the silver, and to give it a more perfect polish; but this polish is factitious, since it is not really in contact on the silver, but is, in fact, on a very fine layer of oxide of iron. It is for this reason that there is required for polishing them a substance which does not adhere to the silver; pumice leaves less residue than any other substance.

As regards the liquid to be employed: in the first operations nitric acid of five degrees must be employed, but for the last operations it must be reduced to one degree. The polishing with oil and the heating may be suppressed.

The layer produced by the descending vapours of the iodine and of the accelerating substance forms with silver a more sensible compound than is obtained with the ascending vapours. I make this observation only to lay down a fact, for it would be difficult to employ descending vapours, on account of the dust which might fall during the operation, and from stains.

The resistance which light experiences in passing through a white glass is well known. This resistance is even greater than it appears, and may be attributed not only to the dust which is left on the glazing in cleaning it, but also to that which is naturally deposited on it. The object-glass of the camera obscura is certainly in the same case. To ascertain this, I put the object-glass in cold water, which I boiled; I knew that it was impossible to remove it without the sides. This operation had, therefore, no other object than to raise the temperature of the glass to 212° F. C., and I then immediately poured on the two sides of the object-glass very pure boiling water to remove the dust. By operating directly with the object-glass, thus cleansed, I still further increased the promptitude. This means presents too many difficulties to be put in practice; only care should be taken to clean the object-glass every day.

The atmospheric dust, which is the scourge of photogenic images, is, on the contrary, favourable to images which are obtained by contact or at a very short distance. To be convinced of this, we have only to clean the two bodies which we wish to put in contact with the boiling water, as I have just indicated, and to keep them both at the same temperature as the air; there will then be no impression, which evidently proves that these images have no relation with the radiation which gives photographic images.

M. Fizeau's Preparation.—The preparation of bromine water is thus described by M. Fizeau:—"To prepare a solution of bromine, of a fixed proportion and convenient strength to operate with, I, in the first place, make a saturated solution of bromine in water; this is prepared by putting into a bottle of pure water a great excess of bromine, agitating strongly for some minutes, and before using allowing the bromine to separate. Now, a definite quantity of this saturated water is to be mixed with a definite quantity of plain water, which will give a solution of bromine always in the same strength: this mixture is conveniently made in the following manner:—The apparatus necessary is a *dropping tube*, which is also required for another part of the process, capable of holding a small definite quantity, and a bottle having a mark to indicate a capacity equal to thirty times that of the dropping tube: fill the bottle with pure water to the mark, then add, by means of the dropping tube, the proper quantity of the saturated solution of bromine.

"The purity of the water is of some importance: the foregoing proportions refer to the pure distilled water, and it is well known that the waters of rivers and springs is not pure; but these different varieties can be used as absolutely pure water by adding a few drops of nitric acid till they taste slightly acid; two or three drops to the pint is generally sufficient.

"The liquid produced, which is of a bright yellow colour, ought to be kept in a well-stoppered bottle; it is the normal solution, and I shall call it simply bromine water, to distinguish it from the saturated solution.

"The box I employ for subjecting the plate to the vapour of the bromine water is constructed in the following manner:—It consists of a box lined with a varnish, which is not acted on by bromine; its height is about four inches; the other dimensions are regulated by the size of the plate, which ought to be at least half an inch all round, short of the sides of the box; it is composed of three separate portions—the cover, which is the frame holding the plate, the body of the box, and the bottom, upon which is placed the vessel for the bromine; this moveable bottom is slightly hollowed, so that the bromine vessel may always be placed in exactly the same position."

Bromide of iodine is prepared by M. Valicour's method thus:—Into a bottle of the capacity of two ounces, pour thirty or forty drops of bromine, the precise quantity not being of importance. Then add, grain by grain, as much iodine as the bromine will dissolve till quite saturated. This point may be ascertained by some of the iodine remaining undissolved. In this state it is too concentrated for use; but by dropping fifteen or twenty drops into half an ounce of distilled or filtered rain-water, the requisite strength may be obtained.

Mr. R. J. Bingham, in an article published in the "Philosophical Magazine," October, 1846, gives an improvement in the Daguerreotype process by the application of some new compounds of bromine, chlorine, and iodine. "In warm weather," he remarks, "a considerable deposition of moisture takes place upon the glass or slate cover used to confine the vapour in the bromine or accelerating pan. This moisture must also necessarily condense upon the cold metallic surface of the plate during the time it is exposed to the bromine vapour. In fact, it is difficult to obtain perfect pictures during the excessive heat of the late season. This appears to be owing to the deposition of moisture upon the plate, arising from the water in which the bromine is dissolved. To obviate this, some have recommended the pan to be kept at a low temperature in a freezing mixture; and M. Daguerre, in a communication to the French Academy of Sciences, recommends the plate to be heated: but in practice both these are found to be unsuccessful.

"It appeared to me, that if we could avoid the use of water altogether in the accelerating mixture, not only would the difficulty I have mentioned be avoided, but a much more sensitive surface would be obtained on the plate. With this view, I endeavoured to combine bromine with lime, so as to form a componnd analogous to bleaching powder. In this I was successful, and find that bromine, chloride of iodine, and iodine, may be united with lime, forming compounds having properties similar to the so-called chloride of lime.

"The bromide of lime may be produced by allowing bromine vapour to act upon hydrate of lime for some hours. The most convenient method of doing this is to place some of the hydrate at the bottom of a flask, and then put some bromine into a glass capsule supported a little above the lime. As heat is developed during the combination, it is better to place the lower part of the flask in water at the temperature of about 50° Fah.: the lime gradually assumes a beautiful scarlet colour, and acquires an appearance very similar to that of the red iodide of mercury. The chloro-iodide of lime may be formed in the same manner—it has a deep brown colour. Both these compounds, when the vapour arising from them is not too intense, have an odour analogous to that of bleaching powder, and quite distinguishable from chlorine, bromine, or iodine alone.

"Those Daguerreotypists who use chlorine in combination with bromine, as in Woolcott's American mixture, or M. Guerin's Hungarian solution, which is a compound of bromine, chlorine, and iodine, may obtain similar substances in the solid state, which may be used with great advantage. By passing chlorine over bromine, and condensing the vapours into a liquid, and then allowing the vapour of this to act upon lime, a solid may be obtained, having all the properties of the American accelerator; or by combining the chloro-iodide of lime with a little of the bromide, a mixture similar to that of M. Guerin's may be produced: but I greatly prefer, and would recommend, the pure bromide of lime, it being, as I believe, the quickest accelerating substance at present known. By slightly colouring the plate with the chloro-iodide, and then exposing it for a proper time over the bromide, proofs may be obtained in a fraction of a second, even late in the afternoon. A yellow colour should be given by the use of the first substance; and the proper time over the bromide is readily obtained by one or two trials. With about a drachm of the substance in a shallow pan, I give the plate ten seconds the whole of the first day of using the preparation, and add about three seconds for every succeeding one. The compound should be evenly strewed over the bottom of the pan, and will last, with care, about a fortnight.

"The great advantage of this compound is, that it may be used continuously for a fortnight without renewal; and, unlike bromine water, its action is unaffected by the ordinary changes of temperature."

M. Fizeau, who has carefully studied this branch of the science, gives the following directions for giving greater permanence to the Daguerreotype picture:—

"Dissolve eight grains of chloride of gold in sixteen ounces of water, and thirty-two grains of hyposulphite of soda in four ounces of water: pour the solution of gold into that of the soda, a little by little, agitating between each addition. The mixture, at first slightly yellow, becomes perfectly limpid. This liquid now contains a double hyposulphite of soda and gold.

"To use this salt of gold, the surface of the plate should be perfectly free from any foreign substance, especially dust; consequently it ought to be washed with some precaution, which might be neglected if it was to be finished by the ordinary mode of washing,

"The following manner generally succeeds the best:—The plate being yet iodised. and perfectly free from grease on its two surfaces and sides, should have some drops of alcohol poured on the iodised surface; when the alcohol has wetted all the surface, plunge the plate into a basin of water, and after that into a solution of hyposulphite of soda.

"This solution ought to be changed for each experiment, and to consist of about one part of the salt to fifteen of the water; the rest of the washing is done in the ordinary way, only taking care that the water should be as free as possible from dust.

"The use of the alcohol is simply to make the water adhere perfectly all over the surface of the plate, and prevent it from quitting the sides at each separate immersion, which would infallibly produce stains.

"When a picture has been washed, with these precautions, the treatment with the salt of gold is very simple. It is sufficient to place the plate on a support, and pour upon its surface a sufficient quantity of the salt of gold, that it may be entirely covered, and heat it with a strong spirit-lamp; the picture will be seen to brighten, and become, in a minute or two, of great force. When this effect is produced, the liquid should be poured off, and the plate washed and dried.

"In this operation the silver is dissolved, and the gold precipitated upon the silver and mercury, but with very different results; in effect, the silver, which, by its reflection, forms the shades of the picture, is in some way darkened by the thin film of gold which covers it, from which results a strengthening of all the dark parts. The mercury, on the contrary, which, in the state of an infinite number of small globules, forms the lights, is augmented in its solidity and brightness by its union with the gold, from which results a great degree of permanency, and a remarkable increase in the lights of the picture."

STEREOSCOPIC PHOTOGRAPHY.

Binocular Vision.—There is scarcely anything more interesting in the study of optics than the theory of binocular vision. Few persons are aware of the fact, that without two eyes it is impossible to form a *correct* judgment of distances; this may, at first sight, appear strange, but the *fact* may be proved beyond a doubt. Previously to my proceeding to do so, I shall mention a few cases to the point. A gentleman, a friend of mine, lost the sight of one of his eyes some couple of years ago, and to this day he cannot measure distances—for instance, it sorely puzzles him to snuff a candle, to dip his pen in an ink-bottle, to take hold of anything a little distance from him, &c., &c.; and it is a curious *fact* that he, and others like him, are nearly always *short* of the object. I knew a lady, who had met with the same misfortune, and have often been amused at seeing her try to pour wine out of a bottle into a decanter, or threading a needle. To descend a little lower in the scale of creation, I had a young cat at one time who lost the sight of one eye, and the mistakes she used to make in playing with a ball were truly laughable. For instance, when the ball would roll away for a few feet, she would make a bound, but could never get within three or four inches of it, and if she made a jump to get on a wall, &c., she invariably fell *short*. These are but a few of the numerous instances that I could mention, but they are enough to introduce the subject. And now for some of the proofs.

Experiment 1st.—Insert the prongs of a fork into a door or wall, about three feet six inches, or four feet from the floor, and on the handle or haft of the fork place a cork upright (Fig. 92). Now provide yourself with a cane, or thin walking-stick, go to the other end of the room, and, shutting one eye, walk briskly up towards the cork, and raising the cane at the moment strike at the cork without any *stop* or *hesitation*, keeping *one eye shut all the time*, the chances are that you will not hit the cork once out of six times.

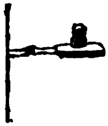


Fig. 92.

Experiment 2nd.—Procure a small piece of pipe-stem, and insert it in the cork of a bottle (Fig. 93). Then stand away from the bottle, about eighteen inches or two feet, and, taking a pointed pencil in your fingers *shut one eye*, and try to place the point of the pencil on the top of the piece of pipe-stem. You may take what time you please to calculate the distance, providing you keep the *one eye shut all the time*, and that you do *not repeat the experiment without withdrawing the hand each time*, the chances are that you will not do it *once in twelve times*. The pipe and pencil appear as in Fig. 94 to the single eye, being a front view; but to any person looking at them from the side they would appear as in Fig. 95 or Fig. 96, but more generally the former.

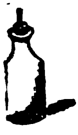


Fig. 93.

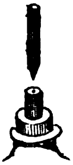


Fig. 94.

Experiment 3rd.—This is by far the most conclusive experiment of the three. Instead of a pipe-stem, procure the end of a quill, or the round end of a *magnum bonum* steel pen, which insert in the cork as in Fig. 97, and, *shutting one eye*, endeavour to drop into the open end of the pen or quill a grain of shot: you may hold the shot within an inch of the pen before you drop it. The chances are you will not drop it in *once in twenty times*. These few simple experiments go far to prove the almost impossibility of calculating distances correctly with one eye.

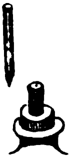


Fig. 95.

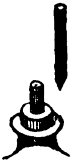


Fig. 96.

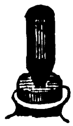


Fig. 97.

The next subject for consideration is, in what manner are we able to calculate distances by using two eyes.

This subject will be more fully explained by the following experiments:—

Experiment 4th.—Stand a book on its edge as in Fig. 98, and so place it that, having the right eye only open, you can see nothing but the back. Shut the right eye and open the left, when the book will appear as in Fig. 99. Of course the same effect would be produced on the other side by using the left eye in the first instance; but if the book be placed exactly between the eyes, then it will appear as in Fig. 100; but not immediately; for as the rays from the eyes can only meet at one point from the latter *at the same time*, or, as it may be considered, the eyes can only *focus* at one point at once, the back of the book appears correctly defined, and the right or left eye sees its own side, *which ever predominates*. It may not be generally known that most persons only use one eye to take in an object or figure, the other being only used to check or determine the distance or relative size of that object, as in the case of focussing in the camera, when you obtain the object perfectly sharp and distinct; then, without altering the eyes or their point of sight, open and shut *one alternately*, and you will at once perceive that *only one eye sees the image properly*. This arises from the fact, that the ray or pencil of light coming through the lens cannot be by any possibility reflected on different points at once. We therefore can see *only one object* at any distance at any one time, although we may be perfectly conscious of other objects nearer or further away. To bear out both these assertions, it will perhaps be necessary to try the following simple experiment:—

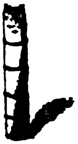


Fig. 98.

Fig. 99.

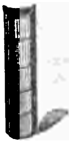


Fig. 100

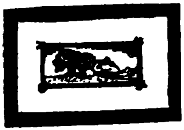


Fig. 101.

Experiment 5th.—Place a small mirror at about two feet six inches from you, and so arranged that it may take in a picture which will about half fill it, and be about eight or nine feet in your rear. This will appear to be exactly in the centre of the mirror, as in Fig. 101. Now, although we are looking at the picture, we are also conscious that the looking-glass is there, and that we can see the frame. Having satisfied ourselves of this, we next proceed to prove that one eye sees more than the other. For instance, shut the right eye—still looking at the picture—and if we see more with the left than the right, the picture will remain in its original position; but if we habitually see more with the right than with the left, then the picture will immediately change over, so to speak, and appear as in Fig. 101. This fact proves, in the first instance, that we cannot see more than one object at once; for although we were conscious of the existence of the frame of the mirror, we could not see it distinctly. And it proves, secondly, that we see more with one eye than the other, or the picture would not change its position in the mirror by shutting or opening the eyes; and thus we have A (Fig. 103), the left eye, and what it sees; B, the right eye, and what it sees; C being the picture.

Fig. 102.

It must be recollected, that the picture being apparently so far behind the mirror, the latter only intersects the rays proceeding to the eyes, as if it were a plain piece of glass *through* which we were looking at the picture (Fig. 104).

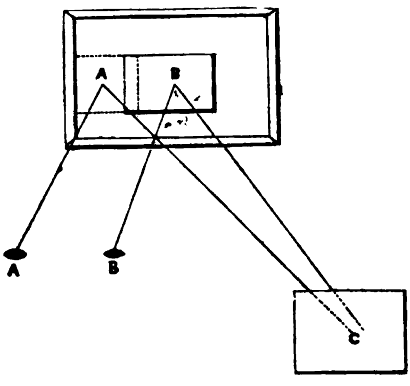


Fig. 103.

The fact of the rays from the eyes meeting, or being *focussed* on an object at a certian distance, and only *on that object at the time*, may be further proved by the following experiments:—

Experiment 6th.—Place a lighted candle about two feet from you, and hold a pencil half the distance between, and in the centre of the eyes (Fig. 105). Now keep all steady and look at C (the pencil) and you will see two candles, one on each side; then look at the candle and you will see two pencils, one on each side. In the former case the pencil will be lighted on each side; and in the latter case the two pencils will be lighted on the inside of each.

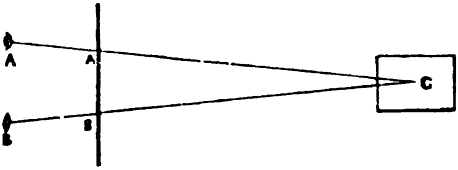


Fig. 104.

The following diagrams will explain this more fully. When looking at the pencil we see, by opening and shutting each eye alternately, the object looked at distinctly, and the other indistinctly, but still we see it; therefore, when looking at the pencil with the left eye, or A, we see it and the candle as in Fig. 106, and with the right eye as in Fig. 107.

At first, from looking at these diagrams, one would think that we saw the pencil at C when looking with both eyes; and were also conscious of one candle at D, as Fig. 107 would lead us to suppose. Here we see Figs. 106 and 107 united (Fig. 108), and would naturally imagine that we would only see one candle and one pencil; but the reverse is the fact, for as one eye is not able to judge of distance, and both are focussed on the pencil at C, they are each conscious of a candle behind C, and naturally bringing the second object into the plane of focus, or nearly so (Figs. 109, 110).

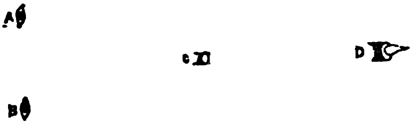


Fig. 105.

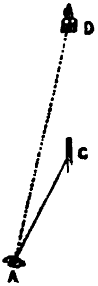


Fig. 106.

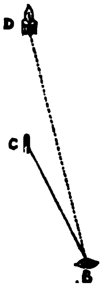


Fig. 107.

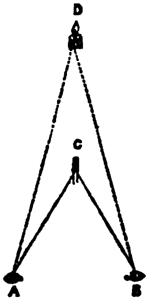


Fig. 108.

The same result occurs in a reverse way when we look at the candle instead of the pencil; but, in this case, the rays cross each other, throwing the pencil back apparently with the candle. But, in the latter case, the left eye, or A, sees the candle and pencil as in Fig. 111; and the right eye, or B, as in Fig. 112.

In all the preceding diagrams, the solid lines represent the line of sight, and the dotted ones the line of light of the figure of the presence of which we are conscious.

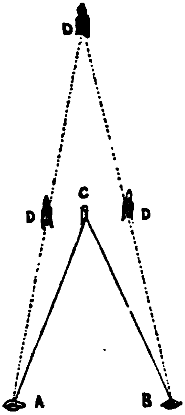


Fig. 109.

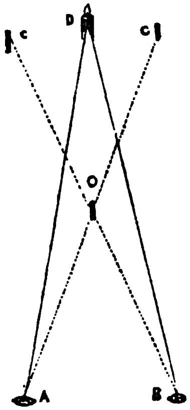


Fig. 110.

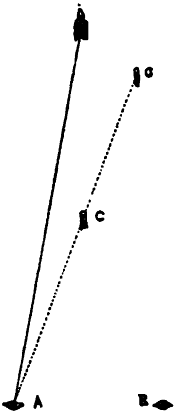


Fig. 111.

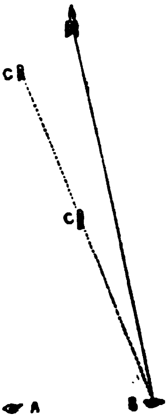


Fig. 112.

The foregoing facts will prove, satisfactorily I hope, that without two eyes we cannot form a correct judgment of distance, and in the same manner of size, form, &c. The next subject will therefore be, how do we take advantage of this fact in photography? We do it simply thus: We consider that a picture or portrait taken by *one* lens and *one* camera is exactly in the position of a similar one looked at by *one eye*; and, to obtain the manifest advantages derived from the use of two eyes, we either employ two cameras and two lenses at certain angles apart, or we take the same view or portrait twice, each taken from a different angle. The former method, for many reasons, is decidedly to be preferred.

The pair of stereoscopic pictures will convey to the mind of the observer (*by means of a properly constructed instrument*) all the effects obtained by the use of two eyes; that is to say, the picture which nature would present to the left eye is seen by the left eye, and that to the right by the right. We therefore observe, when viewing a stereoscopic picture in a stereoscope, that the figures, houses, trees, &c., are perfectly correct as to size, natural position, and relative distance from each other. This fact is so well known, and truly wonderful, that it need not be repeated.

The next subject for consideration will be—

The Stereoscope.—The almost magical effect of two plain flat pictures viewed in the stereoscope is so vivid, when seen for the first time, that the result seems to be a deception of the imagination; in fact, we are inclined to remove the stereoscope and see for ourselves, somewhat like the Indian who went to look behind the looking-glass for the image he saw reflected on its surface. And even when we become accustomed to the use of the instrument we always take a pleasure in looking at the views we may have often seen before; in fact, every object seems to stand out with all the solidity of nature; and in some cases, where the calotype has been properly coloured, the effect, especially in portraiture, is perfectly marvellous.

In the stereoscope, then, we have the most interesting optical instrument ever discovered, reproducing, as it were, in all the reality of nature, the favourite scenes of youth or the semblance of some beloved friend who is gone, perhaps, alas! for ever.

The most simple, most portable, and, I may say, the most correct in principle, is that invented by Sir David Brewster.

This instrument consists of two semi-lenses, placed at such a distance that each eye views the picture or drawing opposite to it, through the margin of the semi-lens, or through parts of it equi-distant from the margin (Fig. 113). A lens, A A′, being cut in two halves, these are fixed into a frame, L and L, and adjusted to such distances that the centres of the semi-lenses correspond with the pupil of the eyes. The distance of the centre of one pupil from the other is at an average of two inches and a half, and to this the semi-lenses may be adjusted; but if the instrument is provided with the means of effecting a little change in this respect, it will often be found to be of considerable advantage.

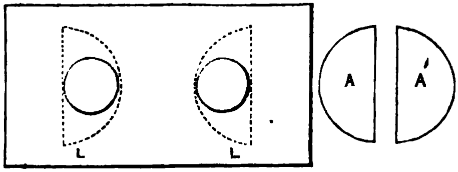


Fig. 113.

Sir David Brewster says, "When we thus view two dissimilar drawings of a solid object, as it is seen by each eye separately, we are actually looking through two prisms, which produce a second image of each drawing; and when these second images unite, or coalesce, we see the solid image which they represent. But in order that the two images may coalesce, without any effort or strain on the part of the eye, it is necessary that the distance of the similar parts of the two drawings be equal to *twice* the separation produced by the prism. For this purpose measure the distance at which the semi-lenses give the most distinct view of the drawings; and having ascertained, by using one eye, the amount of the refraction produced at that distance, or the quantity by which the image of one of the drawings is displaced, place the drawings at a distance equal to twice that quantity; that is, place the drawings so that the average distance of similar parts in each is equal to twice that quantity. If this is not correctly done, the eye of the observer will correct the error by making the images coalesce without being sensible that it is making any such effort. When the dissimilar drawings are thus united, the solid will appear standing, as it were, in relief, between the two plane representations."

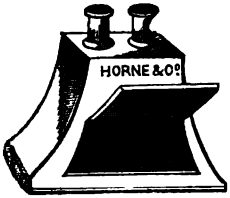


Fig. 114.

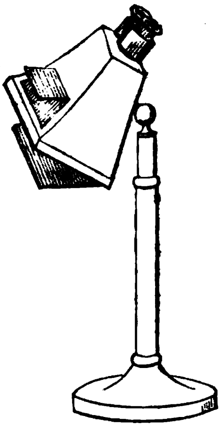


Fig. 116.

The annexed are front and sectional views of the ordinary stereoscope constructed on Sir David's plan (Figs. 114, 115, 116).

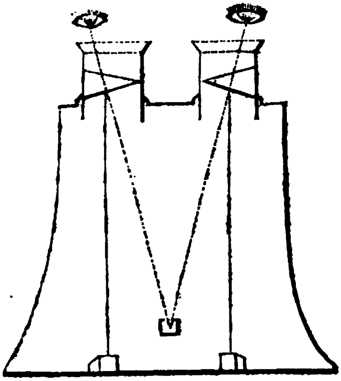


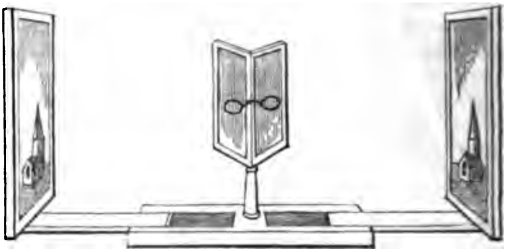
Fig. 115.

Mr. Wheatstone has invented an arrangement which enables us to view larger pictures than we could possibly do in the above. It is called the "reflecting stereoscope," to distinguish it from the lenticular stereoscope, just described.

Two plain mirrors are fixed on a centre support capable of adjustment (Fig. 116.), which is fixed on a mahogany frame into which slide the two arms for holding the pictures. These arms have each adjustments in all directions, so as to bring the two pictures exactly coincident when viewed through the lenses placed in front of the mirrors. These lenses are not essential to the action of the instrument, but add much to the facility of use and beauty of effect. In very perfect instruments, the mirrors are replaced by two polished prisms of glass.

In these stereoscopes the prints must be reversed as they are placed in the drawing, the left-hand one should be the view seen by the right eye in nature, as they are reversed again by being reflected in the mirrors.

There are many rules given for the distance the two cameras should be apart for taking views, &c.; but the reader need not take any trouble about them. The best stereoscopic views ever taken were taken with the two cameras close together. The chief things to be attended to are, that the cameras should be perfectly level, the same height, and that *some object in the view* should come exactly in the centre of each ground-glass. The latter should be lined (Fig. 118), in order that the amateur may at once be able to do so:—



(Fig. 117.)

I need scarcely add that the focus should be perfect in both, and the focal length of the lenses the same. When only one camera is used, it will be necessary to remove it about twelve or fourteen inches, and take care that the same object comes in the centre of the focussing-glass in each case, and that the camera is placed perfectly horizontal and at the same height when moved.

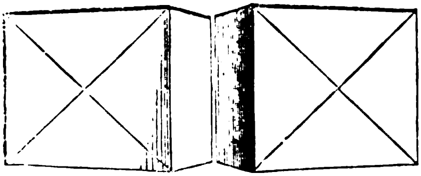


Fig. 118.

Mr. Latimer Clark has published, in the "London Photographic Journal," a very ingenious arrangement for taking stereoscopic pictures with a single camera.

The principle and method of working cannot be better explained than by a reference to his own words.—

"The camera frame, or plate-holder, contains a narrow dark chamber, of the usual construction, capable of receiving a glass plate about 6¾ inches by 3¼ inches. We will call this portion the slide; it slides to and fro freely within the frame through a space of 2½ inches, or 2⅝, which is about the distance between the eyes. To admit of this, the frame must necessarily be 10 or 11 inches long, and it therefore requires some simple adaptation to fit it to the end of an ordinary-sized camera. In the front of the frame is an aperture about 2¼ inches square, closed by a sliding door, and capable of being contracted by an oval or other shaped diaphragm, which determines the size and form of the two pictures impressed on the plate, and which may be varied at pleasure. The distance between the two pictures is determined by the lateral motion of the slide, viz., 2⅝ inches, as stated before. After one of the two images has been impressed, the slide has to be shifted laterally at the same instant, and in the same direction as the camera itself, by means which I will presently describe. The second image is then taken, and the frame removed.

"In the foregoing contrivance it is necessary to obtain the focus by a separate glass; but in the Daguerreotype arrangement the focussing-glass forms part of the apparatus; the slide is here in three pieces: the centre piece is the focussing-glass, which, being hinged at the bottom, does not slide, but falls back out of the way. The two side pieces (each of which is a perfect dark chamber, containing a sensitive plate) are now in a position to be drawn successively into the field of view opposite the front aperture, and the images impressed. This makes a very compact arrangement, and requires no door in front of the frame, the plates being exposed to light only when brought opposite to the central opening (Fig. 119).

"We now come to the means employed to guide the camera in its lateral movement, the object being all the while retained in focus. A strongly-framed camera-stand carries a flat table about twenty inches wide by sixteen, furnished with the usual adjustments.

Upon this are laid two flat bars of wood, in the direction of the object and parallel, and about the width of the camera asunder; they are eighteen inches in length; their front ends carry stout pins, which descend into the table, and form centres upon which they turn; their opposite ends also carry similar pins, but these are directed upwards, and fit into two corresponding holes in the tail-board of the camera. Now when the camera is placed upon these pins, and moved to and fro laterally, the whole system exactly resembles the common parallel ruler; the two bars form the guides, and the camera, although capable of free lateral motion, always maintains a parallel position. In this condition of things, it is only suited to take stereoscopic pictures of an object at an infinite distance; but to make it move in an arc, converging on any object at any nearer distance, it is only necessary to make the two guide-bars approximate at their nearer end so as to converge slightly towards the object; and by a few trials some degree of convergence will be readily found at which the image will remain, as it were, fixed on the focussing-glass, while the camera is moved to and fro; to admit of this adjustment, one of the pins descends through a slot in the table, and carries a clamping-screw, by means of which it is readily fixed in any required position. In order, however, to render the motion of the camera smoother, it is advisable not to place it directly upon the two guides, but to interpose two thin strips of wood lying across them at right angles beneath the front and back of the camera respectively (and which

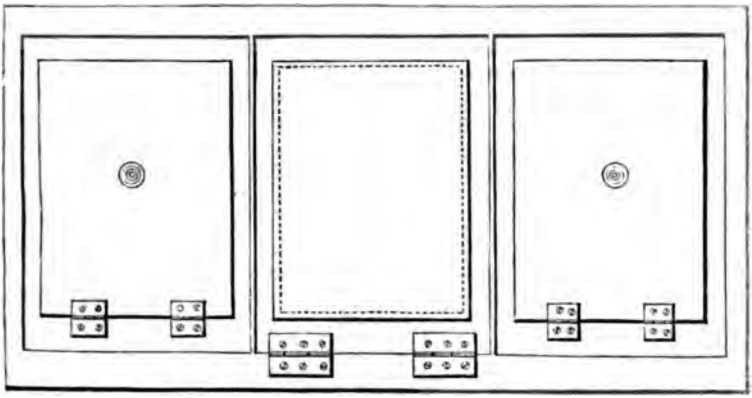


Fig. 119.

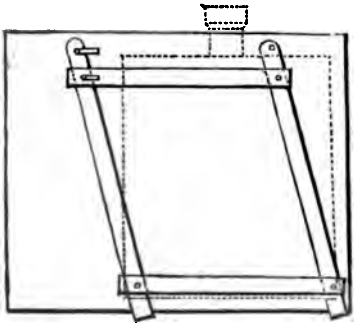


Fig. 120.

may be fixed to the camera, if preferred), and to dust the surfaces with powdered soap-stone or French chalk.

"Lastly, it is necessary that the slide should be shifted laterally at the same instant as the camera. The means used for this are simple, and consist only of a pulley fixed to the right-hand side of the camera, round which passes a string which is temporarily attached to the slide, the other end being fixed to the left-hand side of the table. When the camera is drawn to the left hand, this string is long enough to allow the slide to be drawn to the left hand also; but when the camera is moved to the right, the re-action of the string draws the slide also over in the same direction, the variations in adjustment being compensated by the intervention of an elastic band.

"The operation of taking a portrait is therefore thus performed. The focus having been adjusted for both positions, and the camera and the slide both drawn to the left hand, the door is raised and the plate exposed—say, for five seconds—by one motion of the hand; the camera is then shifted to the right hand, the slide moving at the same time spontaneously; this occupies less than a second of time; and the plate in its new position having been exposed five seconds longer, the door is closed, and the operation completed—the whole sitting having been supposed to occupy eleven seconds."

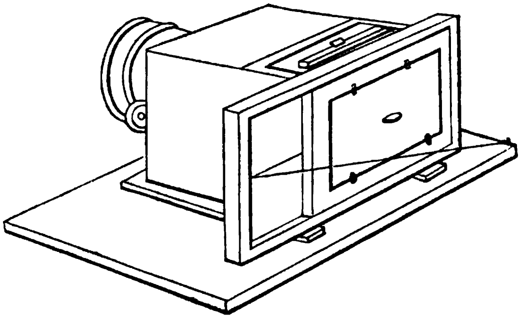


Fig. 121.

The following practical observations by Mr. G. S. Wood will conclude this portion of the present treatise:—

"In the first place, let us ask what it is we have to effect in stereoscopic views? It is simply this—to form upon paper, or glass, or silver (according to the process we may be pursuing), two pictures of the object or objects precisely analagous to those which would be produced on the retinas of the eyes, were we viewing that object or these objects by direct unassisted vision; and the characteristics of those pictures severally should be, that the parts or objects composing such pictures should occupy different relative positions, because, when viewing them in nature, we do so under different angles, or, in other words, that lines drawn from the object or objects under consideration to either eye severally, would form different angles. And it is from the impression which is produced by what may be called the unity of these two pictures (doubtless) in the brain, that we at once have the sensation of rotundity or depth and thickness. And here I would remind those who may not be very conversant with the laws of vision, that the above remark may be easily proved by viewing an object or landscape with *one* eye only; for then all sensation of depth, space, and thickness vanishes; but upon opening the secondeye everything stands out in its proper proportions. And I would also observe that the stereoscope has not, strictly speaking, anything to do with producing those impressions of which we have been speaking, but, as we have before stated, the relative positions of the objects viewed by the two eyes severally. The only use of the optical part of the instrument in question is, that by the aid of half lenses placed in a certain position, we may cause an extraordinary and oblique refraction of the images of the two pictures viewed, in order that they may be produced on those several parts of the retinas, which it should be borne in mind is indispensable in order to give distinct single vision.

"What has to be done, then, in taking these pictures is this:—After having decided upon the position whence our first view is to be taken, to notice, by a contrivance hereafter to be mentioned, the amount of displacement, so to speak, which the objects composing the view undergo when viewed by either eye singly: of course, keeping the head stationary during the observation, and moving the camera either to right or left (as the case may be), to such an amount that the objects composing the picture, produced on the focussing-glass, shall occupy exactly the same relative positions as the objects themselves did when viewed with each eye singly, as before mentioned.

"And thus, after having stated the broad principles to be observed, I now come to what may more immediately be called the *modus operandi* of the whole affair.

"After having placed my camera—I say camera, for I prefer only one—in a chosen position to take the first view, I place a piece of small wire, or a nail will answer all the purpose, in an orifice made to receive it at the top of the frame of the focusing-glass, so that it may project an inch or two above the frame; and having furnished myself with a staff or stick about five feet long, I force this into the ground about six inches or more from the front of the camera, and as near the centre as possible, without the light entering the lens being interfered with. We will suppose the principal portion of the view to be made up of a dwelling-house, I place, say the right eye; about an inch or so from the wire on the top of the frame before mentioned, and closing the left, I now move the head to such a position that the wire and staff may cut each other, or, in other words, that these two and the eye may be in a line, and notice carefully the part of the landscape whereon these conjointly fall; and we may for illustration sake say, that they are produced on the central bar of the left-hand window of the house. I then, without moving the head, open the left eye and close the right, and I now find that the staff has apparently altered its relative position; it now is produced, say on the extreme right-hand corner of the house itself. Having made these observations, I next note the particular part of the landscape falling upon the centre of the ground-glass, and we will suppose this to be the right-hand side of the doorway of the house. I now proceed to take my first picture. Having done this, I move the camera so much to the left that the wire on the top of the camera and the staff, and the right-hand corner of the house, may cut each other (as the two first-mentioned and the bar of the window did in the first observation), at the same time observing that the right-hand corner of the doorway occupies the same psition on the ground-glass as it did previous to taking the first picture. I need hardly add, that in either position the camera should be, as near as can be seen by the eye, at the same level.

"It will at once be seen that it takes infinitely longer to describe the course of procedure than the actually working it out; for the apparatus might be placed in its two positions, and the views taken, all within the space of a few minutes.

I may add, in conclusion, that where these rules are observed in taking stereoscopic pictures, of whatever character the view itself may partake, or however distant some of the objects composing such view may be, they will, when viewed through a stereoscope, convey to the mind impressions precisely corresponding to nature.

Mr. Hardwich gives the following useful hints to the amateur wishing to study the photographic delineation of microscopic objects, for which he acknowledges himself indebted to the personal kindness of Mr. Joseph Delves, of Tunbridge; as he does also to Mr. Shadbolt, for obligingly demonstrating his mode of working with artificial light.

Some of the specimens of micro-photography which have been exhibited are exceedingly elaborate and beautiful; and their production is not difficult to one thoroughly acquainted with the use of the microscope, and with the manipulations of the collodion process. It is important, however, to possess a good apparatus, and to have it properly arranged.

The object-glass of the ordinary compound microscope is the only part actually required in photography, but it is useful to retain the *body* for the sake of the adjustments, and the mirrors used in the illumination. The *eye-piece*, however, which simply magnifies the image formed by the object-glass, is not necessary, since the same effect of enlargement may be obtained by lengthening out the dark chamber, and throwing the image further off.

Arrangement of the Apparatus.—The microscope is placed with its body in a horizontal position, and the eye-piece being removed, a tube of paper, properly blackened in the interior, or lined with black velvet, is inserted into the instrument, to prevent irregular reflection of light from the sides.

A dark chamber of about two feet in length, having at one end an aperture for the insertion of the eye-piece end of the body, and at the other a groove for carrying the slide containing the sensitive plate, is then attached; care being taken to stop all crevices likely to admit diffused light. An ordinary camera may be employed as the dark chamber, the lens being removed, and the body lengthened out, if required, by a conical tube of gutta-percha, made to fasten into the flange of the lens in front. The whole apparatus should be placed exactly in a straight line, that the ground-glass used in focussing may fall at right angles to the axis of the microscope.

The length of the chamber, measuring from the object-glass, may be from two to three feet, according to the size of image required; but if extended beyond this, the pencil of light transmitted by the object-glass is diffused over too large a surface, and a faint and unsatisfactory picture is the result. The object should be illuminated by sunlight, if it can be obtained, but a bright diffused daylight will succeed with low-power glasses, and especially when only *positives* are taken. Employ the *concave* mirror for reflecting the light on the object in the latter case, but in the former the *plane mirror* is the best, except with powers exceeding a quarter of an inch, and of large angular aperture.

The image upon the ground-glass should appear bright and distinct, and the field of a circular form evenly illuminated; when this is the case, all is ready for inserting the sensitive plate.

The time of exposure must be varied according to the intensity of the light, the sensibility of the collodion, and the degree of magnifying power; a few seconds to a minute will be about the extremes; but minute directions are not required, as the operator, if a good photographer, will easily ascertain the proper time for exposing.

At this point a difficulty will probably occur from the plane of the chemical focus not corresponding, as a rule, with that of the visual focus. This arises from the fact that the object-glasses of microscopes are "over corrected" for colour, in order to compensate for a little chromatic aberration in the eye-piece. The violet rays, in consequence of the over-correction, are projected *beyond* the yellow, and hence the focus cf chemical action is further from the glass than the visible image.

The allowance may be made by shifting the sensitive plate, or, what amounts to the same thing, by removing the object-glass a little *away* from the object with a fine adjustment screw; the latter is the most convenient. The exact distance must be determined by careful experiment for each glass; but it is greatest with the low powers, and decreases as they ascend.

Mr. Shadbolt gives the following as a guide:—"An inch and a half objective of Smith and Beck's make, required to be shifted $\frac{1}{50}$ of an inch, or two turns of *their* fine adjustment; a $\frac{2}{3}$ of an inch, $\frac{1}{200}$ of an inch or half a turn; and a $\frac{4}{10}$ of an inch, $\frac{1}{1000}$ of an inch or about two divisions of the adjustment. With the $\frac{1}{4}$ and higher powers, the difference between the foci was so small as to be practically unimportant."

There is also reason to think that the *kind of light* employed has an influence upon the separation of the foci. Mr. Delves finds that with sunlight the difference between them is very small even with the low powers, and inappreciable with the higher; whereas in using diffused day-light, which has undergone a previous reflection from white clouds, it is considerable.

The object glasses of the same maker, and particularly those of different makers, also vary much; so that it will be necessary to test each glass separately, and to register the allowance which is required.

Having found the chemical focus, the principal difficulty has been overcome, and the remaining steps are the same in every respect as for ordinary collodion photographs.

IMPERFECTLY DEVELOPED PROCESSES.

In the preceding pages we have traced the history, step by step, of this wonderful art, through its various stages of Daguerreotype, Calotype, Waxed and Albuminized Paper, and, finally, to the simple and almost perfect Collodion Process. Nevertheless, it must be admitted that numerous indications present themselves, proving that it is yet in its infancy. In this section, therefore, it is proposed to treat of those branches of the subject which are only imperfectly developed, but which are too important to be altogether overlooked. Among these the most remarkable are the results of certain experiments for producing images, with their natural colours, by photogenic action. While numerous experiments have been conducted having this object in view, the American photographers seem to have come closest upon the great desideratum; and the name Hillotype has been given to the process, in honour of the discoverer, Mr. Hill, of West Hill, in the state of New York.

Mr. Hill states that he had undertaken a series of experiments with the object of procuring coloured photographs, but for a long time with little prospect of success; but in one of his experiments certain phenomena presented themselves which greatly surprised him, and persuaded him that the object was attainable. One colour—red—in the figure of a vestment, developed itself in the most brilliant ruby colour; he repeated his experiment many times, but without meeting again the same result, from which he concluded that all the circumstances were not present. Believing, however, that in certain circumstances the latent colour of the image was present, he proceeded with his experiments, and found that the vapour arising from many metals, such as arsenic, cadmium, zinc, selenium, bismuth, potassium, and sodium, possessed the power of developing latent images with their lights and shades. The same result was obtained with different gases, but the images differed little from the usual results; and he was on the point of abandoning the pursuit, despairing of success.

His joy was, therefore, great when he observed one day that his plate presented a perfect impression in colours. He has followed the same experiment with varying results; but in January, 1851, he obtained forty-five designs, which presented all the different colours and with perfect gradations, the objects represented surpassing the richest Daguerreotypes. These pictures are durable, and soft in their aspect; no doubts are expressed of their permanency, and it is stated that the light does not act upon them. Mr. Hill has not described his process further than that it neither resembles that of M. Daguerre, nor M. Becquerel. Another process, which is quicker in its operation, is mentioned, but without details, except that the yellow colour is that he has the greatest difficulty with.

Sir John Herschel had his attention drawn to this subject so early as 1840. "I got," he says, "some specimens of paper *long kept*, which gave a representation of the spectrum in its natural colours, and that *light* on a *dark ground;* but at present I am not prepared to say that they will prove an available process for coloured photographs, *though it brings the hope nearer.*"

M. Biot thinks there are difficulties inherent in photographic pictures, which show that the hopes of the experimenters, who expect to discover the tints of chemical impressions produced by radiation in their natural colours, are illusory.

Mr. Robert Hunt's experiments have, in many instances, given him coloured pictures of the prismatic spectrum *dark* upon a *light ground;* but the most beautiful has been obtained upon the Daguerreotype iodized tablets, on which the colours have at the same time had a peculiar softness and brilliancy. Again, during January, 1854, he prepared some paper with the bichromate of potash and a very weak solution of nitrate of silver, which he exposed behind four coloured glasses, which admitted the passing—1st, of violet, indigo, and blue rays; 2nd, of blue, green, and a portion of yellow rays; 3rd, of green, yellow, and orange rays; and 4th, of orange and red rays. Being allowed to lie for two days—extremely foggy days—opposite a window having a southern aspect, it was found on examination that the paper had become tinted of a blue, green, and red; beneath the yellow glass the change was uncertain, from the peculiar colour of the paper. All this took place without a single gleam of sunshine. This and some other experiments proved to his satisfaction, that the *possibility* admitted by Sir John Herschel amounted to a probability.

M. Becquerel has succeeded in obtaining bright impressions of the spectrum in colours, and in copying highly-coloured drawings on metallic plates prepared with chlorine; and M. Niepce de St. Victor observed that chloride of sodium was employed upon a silver plate plunged into a solution of sulphate of copper, and the plate became more susceptible of receiving a yellow colour than any other.

Looking at these results, and assuming that Mr. Hill's statements are trustworthy, it seems probable that means will be found for producing coloured images both on silvered plates and on paper.

Photography Applied to Lithography.—Some very important applications of the art to engraving on steel and lithographic stone are also named. Among these we may quote the process of Mr. Macpherson, of Rome, as communicated by Mr. Ramsay to the British Association. Mr. Macpherson had succeeded in obtaining beautiful photo-lithographs, specimens of which had been hung up in the Photographic Institution in Buchanan Street, Glasgow. The steps of the process are as follows:—

1. Bitumen is dissolved in sulphuric ether, and the solution is poured on an ordinary lithographic stone. The ether quickly evaporates, and leaves a thin coating of bitumen spread uniformly over the stone. This coating is sensitive to light—a discovery made originally by M. Niepce, of Chalons.

2. A negative on glass or waxed-paper is applied to the sensitive coating of bitumen, and exposed to the full rays of the sun for a period longer or shorter, according to the intensity of the light, and a faint impression on the bitumen is thus obtained.

3. The stone is now placed in a bath of sulphuric ether, which almost instantaneously dissolves the bitumen, which has not been acted on by the light, leaving a delicate picture on the stone, composed of bitumen on which the light has fallen.

4. The stone, after being carefully washed, may be at once placed in the hands of the lithographer, who is to treat it in the ordinary manner with gum and acid; after which proofs may be thrown off by the usual process.

Professor Ramsay then proceeded to state that the above process, modified, had been employed with success to etch plates of steel or copper, without the use of the burin :—1. The metal plate is prepared with a coating of bitumen, precisely in the manner noticed above. 2. A positive picture on glass or paper is then applied to the bitumen, and an impression is obtained by exposure to light. 3. The plate is placed in a bath of ether, and the bitumen not acted upon by the light is dissolved out; a beautiful negative remains on the plate. 4. The plate is now to be plunged into a galvano-plastic bath, and gilded; the gold adheres to the bare metal, but refuses to attach itself to the bitumen. 5. The bitumen is now removed entirely by the action of spirits and gentle heat; the lines of the negative picture are now represented in bare steel or copper, the rest of the plate being covered by a coating of gold. 6. Nitric acid is now applied as in the common etching process; the acid attacks the lines of the picture formed by the bare metal, but will not bite into the gilded surface. A perfect etching is thus said to be obtained.

Application of Photography to Astronomy.—The Roman astronomers state that they have procured photographic impressions of the nebula of the sword of Orion; and Mr. Brooke has invented an apparatus intended for the self-registration of the vertical and horizontal oscillations of the magnet, and the various readings of the barometer and thermometer throughout the day and night, by means of artificial light and photographic paper. This is a very useful and important application of photography to self-registering purposes, and has been found to give perfectly accurate results, and, of course, much more complete than the former system of hourly observations, to make which an assistant had to sit up throughout the night. This invention is altogether due to Mr. Brookes.

The only other application which has hitherto been made of photography to astronomical purposes, so far as we are aware, has been in taking Daguerreotype images of the moon and the solar spots. In the former case, the ordinary preparation of the silvered plate and glass, as used in the Daguerreotype and Collodion processes for taking portraits, is quite delicate enough. A very beautiful image of the moon, when about half-full has been taken in this manner with the great telescope of twenty-three feet focal length and fifteen inches aperture, at Cambridge in the United States. It was taken by Mr. Bond and was four or five inches in diameter. It has likewise been attempted with the great equatorial at the Cambridge Observatory, but the clock motion, for keeping the telescope pointed to the same part of the heavens, has not yet been found steady enough for that purpose, and the photographs obtained have been imperfect. In taking them, the image given by the object-glass alone (without any intermediate lenses) has been received on the plate.

In the case of the solar spots, any ordinary photographic paper is, of course, quite delicate enough. In many observatories an image of the sun's disc has been taken from time to time in this manner.

An image of a *double star* has likewise been taken, but the other remarkable sidereal objects, as nebulæ, clusters, &c., shine with too faint a light to be registered by the most delicate preparation of the plate yet known. It has hitherto failed altogether with Lord Rosse's gigantic reflector, though an image of the moon taken by this instrument would be of great value.

Photographs from Electric Light.—It was at one time assumed that artificial light possessed no chemical rays; but Mr. Brande set aside this notion, having discovered that although the concentrated light of the moon, or even the light of olefiant gas, composed of equal parts of carbon and hydrogen in its most intense form, had no effect on chloride of silver or on chloride and hydrogen. Yet the light emitted by electrized charcoal blackens the salt, while pictures have been taken upon sensitized paper by means of the electric light. For portraits this process is rendered difficult by the intensity of the light affecting the sitter's sight; but for microscopic objects, and especially with the oxyhydrogen microscope, it has been more successful. A correspondent, who pursued these investigations with great success, thus explains himself:—"The object of my experiments was to obtain good photographs of microscopic objects, and having the opportunity of employing Mr. Haite's electric light, I did so with very satisfactory results. I also succeeded in obtaining one or two portraits by it, but the latter were marked by great severity of shadow, even when the light was painfully intense and unpleasantly hot. I concluded therefore that the amount of actinic ray was but small in comparison with the luminous character of the light; the calorific rays were, however, abundant. The same disproportion I have observed with respect to the Drummond light and with gas. While the direct rays are actinic, artificial light does not appear to have the same radiating power on the atmosphere which we observe in solar light, and which produces the fine illumination of objects in partial or complete shadow. This deficiency, I believe, I have observed in some states of the atmosphere in daytime, when, with a comparatively strong light, actinic effects have been feeble, and particularly deficient in the *radiant* quality."

To those who cannot devote their time to photography during the day, Mr. Shadbolt's observation on the use of artificial light may be of service. He employs *camphine*, which appears to give a whiter flame than either gas or the moderator lamp; placing the source of light in the focus of a plano-convex lens of two and a half to three inches diameter (the flat side towards the lamp), and condensing the parallel rays, so obtained, on the object, by a second lens of about an inch and a half diameter and three inch focus.

This mode of illumination, being feeble as regards chemical rays, is best adapted for object-glasses of low power. The exposure required to produce a negative impression with the one-inch glass may be from three to five minutes. The development is conducted in the ordinary manner.

Particular stress is laid upon the object-glass of the microscope being a good one for the purpose; and indeed all who have given attention to the subject are agreed upon this point—that there is a considerable difference in the photographic value of objectives, and this, too, independent of the angular aperture of the glass.

The Rev. W. Towler Kingsley has communicated a process by which very beautiful microscopic photographs have been obtained. He illuminates (in the absence of sunlight) with the brilliant light produced by throwing a jet of mixed oxygen and hydrogen gases upon a small cone of lime or magnesia. His process is as follows:—

It is not necessary to describe the method of making collodion. With it a very small quantity of iodide of silver, dissolved in iodide of potassium or in cyanide of potassium, is mixed. This is now to be poured on a plate of glass, and the excess poured off again, so as to leave a film of the preparation on the glass surface. The plate is now to be plunged into a bath of nitrate of silver, 30 grains to the ounce of water; and as soon as the whole of the plate will retain the water without running into streaks, the plate is to be exposed to the action of the light; it is then to be plunged into a bath of pyrogallic acid, 3 grains; water, 1 ounce; glacial acetic acid, 1 drachm. This deiodizing and deoxidizing bath develops the image; the unreduced iodide is then to be removed by hyposulphite of soda. This is the ordinary process, and the method is simple and good. If we add to the collodion mixture a small quantity of iodide or bromide of iron, and develop with protonitrate of iron, the process is rendered much more energetic; for we obtain on the plate, as soon as it goes into the silver bath, nitrate of iron, which deiodizes the plate as soon as the light strikes it. I do not find these preparations of iron to keep well, and therefore the preparation should be made only a short time before it is to be used. Iodide and bromide of arsenic are also admirable accelerators, and appear to keep for months without change; with them either the pyrogallic solution or protonitrate of iron may be used. I may here mention that albumen, treated exactly the same as the collodion, only dried and heated after being poured on the glass, acts just as well and as quickly.

I shall now describe the method of preparing the paper used. I prefer Canson's paper. I have no doubt that many others are just as good.

It is used either waxed or not, with nearly the same results; but the waxed paper is the more easily managed, on account of its not becoming so tender from soaking. The paper is first to be soaked for some hours in a bath composed as follows:—

Distilled water	1 pint.
Iodide of potassium	half an ounce.
Bromide of potassium	half a drachm.
Fluoride of potassium	1 drachm.
The whites of two eggs.	

If this is done under the air-pump so much the better. The paper is now to be hung up to dry, sheet by sheet; and so prepared it keeps well, certainly for months. If arsenic be added, as in the collodion, the paper is more sensitive. When it is to be used, it is to be plunged into a bath composed as follows:—

Nitrate of silver	30 grains.
Acetic acid	½ drachm.
Distilled water	1 ounce.

After the paper has become saturated in this bath, it is to be placed on a sheet of pure blotting-paper, and that on a sheet of glass, to which it will adhere from the superabundant fluid; it is now to be exposed to the action of the light for the required time, which of course depends upon the intensity of the light; with my microscope, from two to five minutes is quite enough. It is then to be developed in a bath of saturated gallic acid; if the image does not seem dark enough in an hour, a few drops of the silver bath should be added. Hyposulphite of soda, as usual, is the fixing agent. The silver may be used over and over again, if it be filtered with animal charcoal after each time it is used, or as soon as it shows the least sign of becoming discoloured.

In these processes we have the affinity for the iodine disturbed by the action of the light; the developing agent carries this further, and the oxygen of the air or water or acid, which has always a slightly greater affinity than iodine for silver, combines with the liberated silver and produces the dark parts of the impression; if the action is carried still further we get the silver revived; and in the collodion process this produces a positive. To obtain these collodion positives, the quantity of silver in the collodion should be small, and the exposure only for an instant; after the plate is developed and fixed it should be put into a bath containing either aldehyde or grape-sugar, which will revive the silver with great brilliancy. The paper pictures may be developed by placing them in the mercury box; but it is not to be recommended. There is one use of the collodion which is of service. In the use of very high powers with very delicate objects, it is not easy to see the image formed on the vesculine screen, as described hereafter. When, therefore, an approximate focal distance has been obtained, a collodion positive on a small scale of a portion of the image can be taken in a few moments, and so the correctness of the arrangements tried before placing the paper in its place.

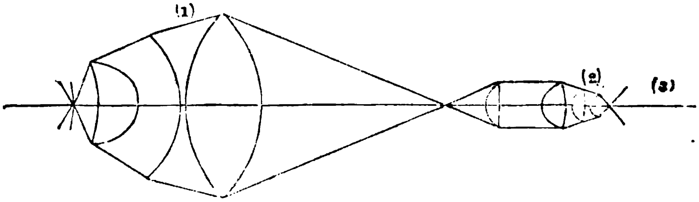


Fig. 122.

I shall now proceed to describe the instrument used. Sunlight is of course far superior to any artificial light, when we can obtain it; but as the sun will not shine whenever we choose, it is of the greatest importance to construct the instrument for artificial light, and then modify it so as to be applicable to sun light. The light I use is the common oxyhydrogen light; magnesia or quartz may be substituted for lime-ball with advantage.

The optical parts of the instrument divide themselves into four groups—the light-collecting, the condensing, the objective and magnifying lenses. The first group (1), for collecting the light, consists of three lenses; the first a meniscus of about three inches focal length and two and a half diameter, the second plano-convex with the radii of the surfaces one and six; the focal lengths of these two lenses being respectively six and eight inches.

The second group, or condensing lenses (2), is a similar one turned the other way, and on a reduced scale, to suit the different object-glasses; between these two systems there is a plano-convex placed at its focal length from the focus of the collectors, so as to allow the rays to pass parallel to the condenser. This lens and the condensers must be changed with the object-glasses; for it must be borne in mind that we have to arrange the instrument so as to make the image of the lime-ball just cover the paper to be acted upon; and if we diminish the focal lengths of the condensers at the same time that we increase the magnifying power of the instrument, we shall have just as great an amount of light with the highest as with the lowest powers.

The next group of lenses are those of the object-glass (3), which requires to be very much under corrected for visible colour, leaving strong red fringes. A very simple way of making the object-glasses of an ordinary good microscope do for photographic purposes is to have a new front lens made for them, so that they can be used for either the ordinary or the photographic microscope. At this point of the arrangement we have a very good form of the oxy-hydrogen microscope; but it is a bad one for photography, as we cannot have the screen on which the image is to be formed so near as to enable us to use the slow motions of the various arrangements at the time we are looking at the image, except for very low powers.

We now come to the last group, which occupies the place of the eye-piece of the ordinary compound microscope. This group is a form of the Ramsden or positive eyepiece, which ordinarily consists of two plano-convex lenses, placed at two-thirds their focal length, which is the same in both, and with their plane sides out (4). This eyepiece is not achromatic, being under corrected. The addition of a plano-concave flint lens to a double convex crown is used in the place of the lens next the object. This enables me, by a slight change of distance, to make the correction perfect.

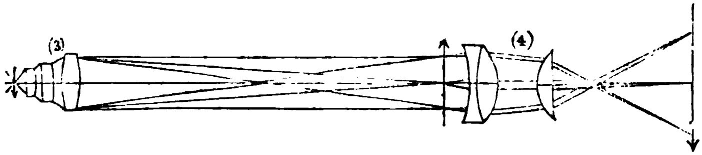


Fig. 123.

I have now only to describe the best way of using this instrument; and here, it must be remembered, that all depends upon the object-glass being good. It is very easy to get one of small angle that will give very sharp outlines of objects, but we must not be content with such images as these; we must get object-glasses of large angular aperture, made perfect for this purpose, so as to show the structure of objects, as well as their outlines. This is quite feasible. Suppose, then, that we have got a perfect instrument.

At the place of the focus of the object-glass place a screen of æsculine, and a dark blue glass between the collectors and condensers; we shall now, "thanks to Professor Stokes," see the chemical image; and the correction for spherical aberration must now be made in the ordinary manner. Now put in the eye-glass or magnifier, and the æsculine at the screen, and adjust the focus. This focus will be found, even in the case of chemically corrected lenses, beyond the visible; but in the case of the ordinary best object-glasses, the difference is enormous; for instance, in the case of a very fine one-fifth in my possession, if I form an image of one foot from the eye-glass, I find the chemical image ten feet further back; of course such a lens is of no use for photography.

The æsculine also enables one to see at once when the light on the screen is the most intense for chemical action.

In conclusion, I have to state that some of my specimens sent were taken upon a disc of five feet diameter, which was illuminated equally; and therefore anything may be taken on that scale on paper with artificial light, and I dare say on a very much larger scale still. I look upon it, therefore, that we must give our chief attention to the corrections of the lenses, as all the other parts of the process seem to require little further than mere care in the use of common formulæ. I have also to add, that the focal length of the condenser being selected, in order to give the image of the incandescent spot of lime on the right scale, its angular aperture should be a shade less than that of the object-glass.

By this process, if a spot of tinfoil be placed on the condenser, we can get the object bright on a dark ground; and if an opaque object be placed in the focus of the collecting lenses, and the object-glass and eye-piece be turned round to the front of the object, a very good image may be got with low power.

Photographs on Wood.—Among other applications of this art, we must not omit to name it as an aid to the wood-engraver, to the extent of giving a perfectly faithful tracing of the landscape or portrait which he proposes to engrave. At the first page of our treatise we have given the negative and positive of a very characteristic portrait traced on the wood by this process, and engraved without penciling after it had been laid aside for nearly two years. It was supposed for a long time that the chemical means required to make the wood sensitive to the actinic action would destroy its fibre, and render engraving impossible; but this is not the case. The correspondent who kindly made these experiments for us thus explains himself. After explaining the difficulties experienced from imperfect apparatus, he says:—

"I must tell you what I conceive I have achieved by this block, and point out the probabilities of ultimate success. I have produced a positive picture without staining the wood, and which is removable when the engraving is done, should that be necessary. All, then, that remains to be done is to get a perfect negative, that will give a reverse image on the wood; and this may be accomplished in this manner:—The cameras constructed for Daguerreotypes have a reversing prism, which gives a correct image, and consequently would produce a correct negative; when this is transferred to the wood, it would produce a reverse positive picture (the thing wanted). I should wish to have this block engraved and printed, to make sure that there is nothing on the wood itself to prevent or interfere with the printing process. I am sure there is nothing to interfere with the engraver's art, as the scratch of a pin reveals the white wood. I consider, that if the engraving and printing are successful, the success of the other part is certain. There are a great many chances yet of something else turning up; but it would require a camera constructed on purpose, so as to allow blocks of wood to be adjusted in it—no very difficult problem. I can produce a white picture on a black ground directly from the object; but I much fear that the blackening of the wood would spoil the block for the engraver; and also, I think this promises to answer every purpose."

Colouring Photographic Pictures.—Artificial colouring, whether applied to Daguerreotype or photography, is by no means a happy idea. To colour them in a satisfactory manner requires the talent of a first-class miniature painter; and it need not be stated that this can rarely be obtained. Nevertheless, some of our readers may desire to try the experiment; we transcribe here various colouring processes for those so disposed.

Nearly, if not quite all the various colours used in painting may be made from the five primitive colours, black, white, blue, red, and yellow; but for the Daguerrean artist it would be the best policy to obtain such as are required by their art already prepared. In a majority of cases, the following will be found sufficient, viz., carmine, Prussian blue, white, chrome yellow, gamboge, for drapery; yellow ochre for the face, or all three; light red; indigo; burnt sienna; bistre, or burnt umber.

If, in colouring any part of a lady's or geutleman's apparel, it is found necessary to produce other tints and shades, the following combinations may be used:—

Orange—Mix yellow with red, making it darker or lighter by using more or less red.

Purple—This is made with Prussian blue, or indigo and red. Carmine and Prussian blue producing the richest colour, which may be deepened in the shadows by a slight addition of indigo orbrown.

Greens—Prussian blue and gamboge makes a very fine green, which may be varied to suit the taste of the sitter or operator, by larger portions of either, or by adding white, burnt sienna, indigo, and red, as the case may require. These combinations, under different modifications, give almost endless varieties of green.

Brown—May be made of different shades of umber, carmine and lamp-black.

Neutral tint—Is composed of indigo and lamp-black.

Crimson—Mix carmine and white, deepening the shaded parts of the picture with addititional carmine.

Flesh colour—The best representative of flesh colour is light red, brightened in the more glowing or warmer parts with carmine, softened off in the lighter portions with white, and shaded with purple and burnt sienna.

Lead colour—Mix indigo and white in proportions to suit.

Scarlet—Carmine and light red.

For jewelry—Cups of gold and silver preparations accompany each box for Daguerreotypists, or may be procured separately.

The method of laying colours on Daguerreotypes is one of considerable difficulty, inasmuch as they are used in the form of perfectly dry impalpable powder. The rules we shall give for colouring Daguerreotypes depend, and are founded, upon those observed in miniature painting, and are intended more as hints to Daguerreotype artists in hopes of leading them to attempt improvements, than as instructions wholly to be observed.

The writer is confident that some compound or ingredient may yet be discovered which, when mixed with the colours, will give a more delicate, pleasing, and natural appearance to the picture than is derived from the present mode of laying them on, which in his estimation is more like plastering than colouring.

In colouring Daguerreotypes, the principal shades of the head are to be made with bistre mixed with burnt sienna, touching some places with a mixture of carmine and indigo. The flesh tints are produced by the use of light red, deepened towards the shaded parts with yellow ochre, blue, and carmine mixed with indigo, while the warmer or more highly-coloured parts have a slight excess of carmine or lake. Colour the shades about the mouth and neck with yellow ochre, blue, and a very little carmine, heightening the colour of the lips with carmine and light red, letting the light red predominate on the upper and the carmine on the lower lip; the shades in the corner of the mouth being touched slightly with burnt sienna mixed with carmine.

In colouring the eyes, the artist will of course be guided by nature, observing a very delicate touch in laying on the colours, so as to preserve as much transparency as possible. A slight touch of blue—ultramarine would be best if it would adhere to the Daguerreotype plate—in the whites of the eyes near the iris, will produce a good effect.

In colouring the hands of men it will be necessary to use the darker tints with more freedom, according to the complexion of the sitter. For women the warmer tints should predominate, and in order to give that transparency so universal with the softer sex—and which gives so much loveliness and beauty to the face—a little white may be judiciously intermingled with the red tints about the lighter portions of the face.

In taking the likeness of a lady with light or auburn hair, by the Daguerreotype process, much of the beauty of the face is destroyed, on account of the imperfect manner in which light conveys the image of light objects to the spectrum of the camera; and this, I conceive, is an instance where defects may be obviated in some measure by proper colouring. To do this touch the shaded parts with burnt sienna and bistre, filling up the lighter portions with yellow ochre, delicate touches of burnt sienna, and in those parts which naturally have a bluish tint, add very delicate touches of purple—so delicate, in fact, as hardly to be perceived. The roots of the hair at the forehead should also be touched with blue, and the eyebrows near the temples made of a pinkish tint. The chin of a woman is nearly of the same colour as the cheeks in the most glowing parts. In men it is stronger and of a bluish tint, in order to produce the effect given by the beard.

In portraits of woman—the middle tints on the side of the light, which are perceived on the bosom and arms, are made of a slight mixture of ochre, blue and lake, (or carmine), to which add, on the shaded sides, ochre, bistre, and purple; the latter in the darker parts. The tints of the hands should be the same as the other parts of the flesh, the ends of the fingers being a little pinkish and the nails of a violet hue. If any portion of the fleshy parts is shaded by portions of the dress, or by the position of the hand, this shade should be coloured with umber mixed with purple.

To Colour the Drapery.—*Violet velvet.*—Use the purple made of Prussian blue and carmine, touching up the shaded parts with indigo blue.

Green velvet.—Mix Prussian blue and red orpiment, shade with purple, and touch up the lights with a little white.

Red velvet.—Mix a little brown with carmine, shading with purple, marking the lights in the strongest parts with pure carmine, and touch the most brilliant slightly with white.

White feathers—May be improved by delicately touching the shaded parts with a little blue mixed with white. *White* muslin, linen, lace, satin, silk, &c., may also be coloured in the same way, being careful not to lay the colour on too heavily.

Furs.—*Red furs*—may be imitated by using light red and a little masticot, shaded with umber.

Gray furs—black and white mixed and shaded with bistre.

Sable—white shaded lightly with yellow ochre.

These few directions are quite sufficient for the art, and it is quite unnecessary for me to pursue the subject further. I would, however, remark that the Daguerreotypists would find it greatly to their advantage to visit the studies of our best artists, our public galleries of paintings and statuary, and wherever else they can obtain a sight of fine paintings, and study the various styles of colouring, attitudes, folds of drapery, and other points of the art. In colouring Daguerreotypes, artists will find the magnifying glass of much advantage in detecting imperfections in the plate or in the image, which may be remedied by the brush. In selecting brushes choose those most susceptible of a fine point, which may be ascertained by wetting them between the lips or in a glass of water.

Glycerined Collodion.—I need scarcely tell the reader that there are, discoveries in Photography being made daily. Even while this treatise is going through the press, several of importance have been published, both in the chemical and mechanical part of the science; for instance, in close alliance with the moist collodion, the honey collodion, and the collodio-albumen processes, comes the employment of glycerine for the purpose of preserving the sensitiveness of collodion for a lengthened period. Mr. H. Pollock writes as follows:—

"I have lately adopted a mode of applying glycerine to collodion plates in order to make them keep, which is, I believe, new, and which, from its simplicity and (as far as I have tried it) certainty, will, I trust, prove of general utility.

"1. To ordinary collodion add glycerine in the proportion of six drops to the ounce.

"2. Make a nitrate of silver bath in the usual manner, except that, instead of distilled water, a mixture of glycerine and distilled water, in the proportion of one of the former to five of the latter, is to be used.

"3. Make a second bath, containing only six grains of nitrate to the ounce.

"4. Coat the plate with 1, and immerse it in 2, in the usual manner, after which immerse it in 3, for a minute; drain it as usual, and you have a keeping plate, which I find to be as good at the end of a week as when fresh from the bath.

"5. Before developing, moisten the plate with distilled water, then proceed as usual, taking care to add two drops of a 50-grain solution of nitrate of silver to the developing solution before pouring it on to the plate.

"Note 1. For a short time I imagined (contrary to my expectation) that glycerine did not decompose a solution of nitrate of silver; I was, however, misled by the slowness of the action, for it does produce decomposition, although very slowly, even in the dark. This does not appear to damage the bath (it certainly does not for a month), but makes it necessary to filter it about once a week. In time the bath would probably become alkaline and require the addition of fresh nitrate and acetic acid.

"Note 2. Six drops of glycerine to the ounce of collodion is perhaps a maximum dose. If too much is added, the film will have a honey-comb structure; the quantity which can be added without producing this, will vary with the quantity of water present in the collodion; hence the collodion best fitted for this process is that made with anhydrous ether and alcohol, and it must be borne in mind that in actual use the proportion of glycerine will gradually increase, because the ether and alcohol evaporate, but the glycerine remains.

"Note 3. If Note 1 is supposed to contain an objection to this method, a horizontal bath can be used holding but little, and a new bath be mixed once a fortnight.

"Note 4. The glycerine used is prepared, by decomposing fats by high-pressure steam, by Price's Patent Candle Company, and which can be easily procured.

"Note 5. My experience of this process is very short. I therefore have given proportions, not as being the best, but such as I have found succeed. More extended experience must show what is the minimum of glycerine which will produce the maximum keeping effect."

And Mr. Maxwell Lyte has brought before the world a new system of printing which "depends on the power which aqua regia possesses of destroying sulphide of silver, or any similar compound of sulphur, converting the metal into a chloride, while at the same time the combined sulphur becomes sulphuric acid. The sulphur thus becomes soluble, while the silver takes the form of a chloride; and having thus got rid of the sulphur, we again darken the chloride of silver by acting upon it with a combination of gallic acid and potash, which reconverts it to the black metallic state. Take ordinary positive paper. The papier Saxe is, perhaps, most suited to the purpose, as giving the greatest fineness and most perfect definition. Having chosen the right side, lay that side downwards on a solution of chloride of ammonium of five per cent. When it has thoroughly imbibed, lift it off, and hang it up to dry; then lay the same face down on a bath of nitrate of twenty per cent., and after it has been for at least five minutes in contact with this bath, again suspend it to dry.

"Print the picture in the usual way, only let it be printed somewhat darker than will be ultimately required, as the after process tends rather to tone it down.

"The print withdrawn from the pressure-frame must now be placed in a bath of plain water, in order to extract as much as possible of the free nitrate; then in a bath of water in which is dissolved a little salt. This converts all the free nitrate remaining in the proof into chloride of silver, and from thence it is to be carried to a bath of new hyposulphite of soda of 25 per cent., to which has been added 0·5 per cent. of carbonate of soda. Here it is to remain till fixed, which process may be deemed accomplished after it has lain for from a quarter of an hour to half an hour in the bath. It is now to be thoroughly washed in several waters till all the hypo be removed.

"The picture will now be most probably of an ugly red colour, the more strongly so in proportion as the hypo is more freshly made; and if by age of the hypo the picture may happen to be of a better tone, then the presence of sulphide of silver in the proof always seems to threaten its destruction if left there, but the existence of which the following treatment obviates. The well-washed and still wet proof is now placed in a bath composed of aqua regia, eight or ten parts; water, one hundred parts. Here it is seen rapidly to fade, and after a short time will have almost completely disappeared, the dark silver forming the picture having all become converted into chloride; while the sulphur, if any there is, is at the same time converted into sulphuric acid, and dissolved out into the liquid. It is now transferred into a bath of water, to which has been added a morsel of carbonate of soda, or a few drops of ammonia, so as to get rid of the acid, and may then be placed in the following bath:—Water, one pint; gallic acid (saturated solution in alcohol), two or three drops; liquor potassæ, one drop; to be mixed at the moment of using. In this mixture the proof rapidly darkens, re-appearing in all its minutest details, and requiring no further treatment than a slight washing in clean water, when it has arrived at its maximum of intensity.

"I may here add a few remarks. The paper employed for this process should not be sized with gelatine, albumen, or any other animal preparation, but with the vegetable preparation used for the machine-made papers which are made on the continent.

"The bath of gallic acid absorbs oxygen very rapidly from the atmosphere, becoming red, so it soon spoils; therefore the ingredients should not be put together until the moment when they are required for use. The small quantity of these substances used at each time prevents all question as to expense, and the time employed in producing a picture scarcely, if at all, exceeds that demanded by any other process, long as this description may appear. This method is, of course, equally applicable for the treatment of positives made by the negative process, *i.e.*, by development; but to my idea this last-named process possesses one great disadvantage, viz., our being unable to watch the progress of the printing, and thereby to stop it at just the right point—a condition absolutely necessary to the production with certainty of perfect positives.

"As the above mode of printing abstracts all the size from the paper, it is necessary either to resize it, or to rub it over with an encaustic prepared thus: take some white wax and dissolve it in turpentine to form a mixture of about the consistence of pomatum, and add to this a quantity of alcohol equal in bulk to half the turpentine employed. Having then fixed the proof either into a frame for stretching drawing-paper in, or having pasted it on a piece of paper and fixed it down, rub into the face of it the paste of wax, &c., and as quickly rub it off with a piece of clean flannel. Enough of the wax remains on the face of the picture to render it beautifully bright and clear, and at the same time to render it impervious to air and moisture, and it may be now cut down and mounted.

"Lastly, as each paper sensitized extracts from the bath a certain amount of nitrate, it becomes necessary to add, for each whole sheet or number of small sheets equalling a whole sheet, which have been sensitized, one drachm of nitrate of silver in crystals, adding at the same time water to make up the quantity of the liquid to its original volume; and also, to avoid loss by the drip from the paper when hung up, it is well to draw its lower surface, *i.e.*, the side which has lain on the bath, over a glass rod held in an oblique position in such a manner as that the liquid which it scrapes off from the face of the paper may fall back again into the bath."

SUMMARY OF PROCESSES FOR PREPARING PAPER.

1. *Bayard's Process.*—Take some drawing-paper, spread over it a solution of bromi~~n~~e d of potassium, afterwards a solution of nitrate of silver; expose this paper for some minutes to the action of light in a dark room; make the image visible by means of mercurial vapour, as in Daguerre's process.

2. *Becquerel's Process.*—A modification of the method of Panton, which see.

3. *Chenning's Process.*—1st. Dissolve sixty grains of nitrate of silver in one ounce of water. 2nd. Dissolve ten grains of iodi~~n~~e of potassium, or a mixture of one part of d bromine of potassium and two parts of iodine of patassium, in one ounce of water. 3rd. Wash the paper with the first, and afterwards with the second solution, and dry it.

4. *Cundell's Process.*—1st. Spread over the paper a solution of thirty grains of nitrate of silver. 2nd. Plunge it into a solution of iodine of potassium, two hundred grains of this salt in seven thousand parts of water, to which add thirty grains of sea salt. Place the prepared side of the paper in contact with the surface of this liquid. 3rd. Leave the paper for five or six minutes floating on the distilled water, dry it in the air, and press it and make it smooth. 4th. Make the impression appear by a solution of concentrated gallic acid, mixed with the same quantity of solution of nitrate of silver, fifty grains of salt, dissolved in one ounce of distilled water, and with a sixth part of acetic acid.

5. *Daguerre's Process.*—Chloride of silver paper. Take some paper slightly covered with isinglass, plunge it in hydrochloride water dried in the open air. When dried put it on the prepared side in contact with a solution of nitrate of silver; dry it and preserve it without exposing it to the light.

6. *Fyfe's Process.*—1st. Dip the paper in a solution of phosphate of potash (one part of this salt in eight parts of water), then dry it. 2nd. Cover it, with the help of a paint brush, with a solution of nitrate of silver (one part of this salt in six parts of water), then dry it again. 3rd. Dip it a second time in the solution of phosphate of potash. 4th. Fix the impression by means of a spreaded solution of one part of ammonia in six parts of water, which will only dissolve the salt of silver, not impressed by the light, whilst it does not affect the blackened salt.

7. *Gaudin's Process.*—1st. Expose the paper during one minute to the vapour of

of hydrochloric acid. 2nd. Cover it over with a solution nearly saturated with nitrate of silver. 3rd. Develop the image, after the action of light in the dark room, covering the paper with a concentrated solution of sulphate of iron slightly acidulated with sulphuric acid. 4th. Fix the image by washing with water containing a tenth part of caustic ammonia.

8. *Process of Heeron.*—1st. Plunge some thin white paper, for a quarter of an hour, in a solution of nitrate of silver, prepared by mixing one part of salt in five parts of water; then plunge it for the same space of time in a solution saturated with sea salt; wash it with distilled water, press it out and dry it between sheets of blotting-paper.—*Note.* This photographic paper is used to judge of the intensity of light in the preparation of Daguerreotype plates.

9. *Herschel's Process.*—1st. Mix, with the help of a gentle heat, a solution of nitrate of silver, of 1·200 density, with two parts of tartaric acid of 1·023 specific gravity, by treating the ferro-tartaric of ammonia with acetate of lead, and decomposing the precipitate with diffused sulphuric acid. 2nd. Wash the paper again with this solution and dry it in the dark.

10. *Herschel's Chrysotype Process.*—1st. Dip the paper in a solution of one hundred grains of crystallized ammoniacal citrate of iron in one hundred grains of water. 2nd. Let it be half-dried. 3rd. Develop the image by a solution of chloride of gold dissolved in water, completely neutralized by potash. 4th. Dip it at first into the water, then for two minutes in a solution of iodine of potassium; then wash it again in the water.

11. *Herschel's Cyanotype Process.*—1st. Dry in equal portions a conceptrated solution of corrosive sublimate with a solution of ammoniacal citrate of iron, mixed with eleven parts of water. 2nd. Cover the paper with it, and dry it. 3rd. Wash the image with a concentrated solution of cyano-ferrate of potash, mixed with three times its volume of gum-water.

12. *Horsley's Process.*—1st. Dip the paper in a watery dilution of sea salt, or one hundred and twenty grains of sal-ammonia in one ounce of water, and dry it. 2nd. Impregnate the paper with a liquor made of a mixture of one hundred and eighty grains of ammonia, sixty grains of nitrate of silver, and five grains of suberic acid, and dry it by the fire. 3rd. Leave it from five to ten minutes in the camera. 4th. Fix the image with hyposulphate of potash, wash the paper, and dry it by the fire.

13. *Hunt's Process.*—1st. Dissolve one part of nitrate of silver in four parts of distilled water, and cover one side of the paper with this solution. 2nd. Dip the paper, after drying it, in a solution of iodine of potassium (one part of the salt in eight parts of water), leave it there during one minute, and wash it afterwards with distilled water. This paper will keep a long time, and can be rendered sensitive immediately by washing it with a solution of cyano-ferrate of potassium (one part of salt in four parts of water).

14. *Hunt's Energetype Process.*—Wash the paper with a saturated solution of succinic acid one hundred and twenty grains, ninety grains of water, and thirty grains of gummy mucilage. 2nd. Dry the paper, and spread over it a solution of nitrate of silver (sixty grains of salt in thirty-seven grains of distilled water). This paper, which may be preserved white, should remain from two to eight minutes in the dark chamber. The impression is developed by a mixture of sixty grains of sulphate of iron and one hundred and twenty to one hundred and eighty grains of gummy mucilage, and is fixed by washing with the ammonia on a solution of hyposulphate of potash.

15. *Kobell's Process.*—1st. Dip the paper into a solution of sea salt (one part of salt

in fifteen of water). 2nd. Dry it, and place it in a flat vessel containing a solution of nitrate of silver. 3rd. Fix the image by means of caustic ammonia, or hypo-sulphate of potash. After fixing the impression, the salt is removed by washing with water.

16. *Martin's Process.—Negative Impression*—1st. Spread over the paper a solution of thirty-six grains of iodine of potassium in one drachm of water. 2d. Dry it in blotting-paper. 3rd. Lay over it a solution of fifty-six grains of azotate of silver in one drachm of water. 4th. Dry it with another clean sheet of blotting-paper. 5th. Repeat all these operations. 6th. Wash it with distilled water with a paint-brush, and dry it in blotting-paper. 7th. Expose it in the dark chamber. 8th. Wash it over with dissolved gallo-nitrate of silver, twenty-seven grains of gallic acid azotate of silver, in one drachm of water. 9th. Wash it with distilled water. 10th. Spread it over twice with a solution of iodine and bromine of potassium, wash it two or three times with distilled water, and dry it thoroughly. *Positive Image*—1st. Cover the paper two or three different times with a solution of nitrate of silver, moisten it with a dabber of cotton wetted through with gallic acid, dry it with care; when the image appears, bring it out with a solution of gallic acid, then dry it. 2nd. Let the paper float on the surface of distilled water for three or four minutes; wash it with a solution of one part of hyposulphate of soda in eight or ten parts of water, then wash it two or three times in distilled water.

17. *O'Shaughnessys's Process.*—Substitute a solution of gold for one of nitrate of silver. The images thus obtained have, it is said, more brilliant tints, with shades of red, purple, and green.

18. *Osann's Process.*—This process consists in the employment of a solution of formate of silver in water. The author prepares this production by means of double decomposition, using sulphate of silver in a concentrated solution of formate of barytes. Fix the image by plunging it several different times in warm water.

19. *Panton's Process.*—Dip the paper in a concentrated solution of bichromate of potash and dry it rapidly by the fire. The image is yellow on an orange ground. If to the bichromate of potash is added sulphate of indigo, various different shades of green will be obtained, and a deepened tone.

20. *Schaffhæult's Process.*—1st. Dissolve two parts and a half of nitrate of silver in six parts of distilled water. 2nd. Pour this solution into a large flat dish, and in it dip one side of the paper. 3rd. Expose this paper, while damp, to the action of the boiling vapours of hydrochloric acid. 4th. Dry it, and in order to render it yet more sensitive, pass it once more upon the solution of nitrate of silver. 5th. Fix the image by plunging the paper for five or ten minutes in alcohol; dry it, and pass it through some diffused hydrochloric acid, in which some drops of pernitrate of mercury have been poured; wash the image with distilled water, and dry it at about 60°.

21. *Schaffhæult's new Process.—Positive Images*—1st. Use paper impregnated with chloride of silver, after the method which has just been shown. 2nd. Let it blacken in the light, and during half an hour keep it plunged in a liquor composed of nine to ten parts of alcohol, and one part of a solution of pernitrate of mercury. 3rd. Pass it quickly over the diffused hydrochloric acid (one part acid and seven to eight parts of water). Wash it rapidly in water, and dry it by a mild heat. This paper is whitened by the rays of the sun, and the images fixed by plunging it in the alcohol, which dissolves the excess of the corrosive sublimate.

22. *Smith's Process* (Tritypic).—1st. Dissolve two grains of carbonate of soda in four grains of water. Filter the solution, and add to it twelve drops of sulphuric or

hydrochloric acid. 3rd. Cover the paper again with this liquor, and dry it in the dark. With this paper is obtained, after twenty minutes to an hour and a half, positive copies of prints. The lights are yellow, the shades violet; by using a double quantity of acid red shades are obtained.

23. *Talbot's Process* (Chloride of Silver Paper).—1st. Choose some thin letter paper, dip it into a weak solution of sea salt, and dry it with a linen rag. 2nd. Spread over one side only, a solution of nitrate of silver (a solution saturated and diffused with six or eight times its weight of water), and dry it slightly.

24. *Talbot's Process* (Bromine of Silver Paper).—Cover some good common paper with a solution of nitrate of silver, then with dissolved bromine of potassium, then again with dissolved nitrate of silver. *Note.* After each operation, care must be taken to dry the paper by the fire.

25. *Talbot's Process* (Calotype).—1st. Prepare the four following liquids:—First liquid, one hundred grains of nitrate of silver dissolved in two hundred and fifty grains of distilled water. Second liquid, five hundred grains of iodine of potassium dissolved in seven thousand grains of distilled water. Third liquid, one hundred grains of nitrate of silver dissolved in two ounces of distilled water; to this solution add a sixth part of its quantity of acetic acid. Fourth liquid, a saturated solution of crystallized gallic acid. 1st. Spread the paper over, one side only, with liquid No. 1, and dry it with care by the fire. 2nd. Dip it in liquid No. 2, and let it remain from two to three minutes; afterwards place it in a glass vessel, and dry it, first between sheets of blotting-paper, afterwards by the fire; keep it in darkness; before making use of it, spread over again a mixture of equal parts of Nos. 3 and 4. Dip it for half an hour in water, dry it, at first, between blotting-paper, then by the fire.

This paper is left only a few minutes in the dark-room, and the image is made visible by spreading over the mixture of liquids indicated (gallo-nitrate of silver). To fix it, the paper is plentifully washed; it is dried between sheets of paper; it is passed with rapidity over one hundred grains of dissolved bromine of potassium in one hundred and forty-eight to three hundred and ten grains (eight to ten ounces) of water; it is once again washed and dried.

26. *Taylor's Process* (a modification of Talbot's method).—1st. Impregnate the paper with a solution of nitrate of silver in ammonia. 2. Fix the images by plunging the paper in boiling water, and leaving it there for two or three days.

27. *Verignon's Process.*—1st. Wash the white paper with water containing a small quantity of hydrochloric acid, and dry it. 2nd. Let it imbibe a solution formed of two parts of sal-ammonia, one part of chloride of strontium, and twenty parts of water; and dry it. 3rd. Dip it into a solution of silver much diffused. 4th. Blacken it by exposing it for half an hour to the action of light. 5th. Let it be impregnated with a very suffused solution of iodine of sodium in the dark, and place it yet wet in the dark-room. The action is finished at the end of twelve minutes. The image is fixed by employing a very diluted solution of hypo-sulphite of silver and iron; after which it is washed in distilled water.

28. *Wood's Process.*—1st. Dip the paper in water, of which three ounces contain two drops of hydrochloric acid. 2nd. Wash it with a mixture of iodine of iron, half a drachm, and one drop of the tincture of iodine in a drachm and a half of water. 3rd. Dry it with blotting-paper, and wash it evenly over with a solution of nitrate of silver (thirty grains of salt in three ounces of water).

THE CHEMISTRY OF FOOD.

BOOK THE FIRST.

§ 1. **On the Formation of the Blood.**—In former times it was conjectured, and, as it were, instinctively asserted, that the human body changes its material and properties at certain epochs of life; and this has been proved to demonstration by the investigations of physiologists during the present century. Though we cannot determine whether the body is renewed entirely in seven years, as is popularly believed, or in a much shorter period, as science has endeavoured to prove; yet we know that all nutriment passes only through the body. By this, however, it is not meant, that what has been received by the mouth is immediately voided. On the contrary, the different ingredients of which our daily aliment is composed become, in reality, essential constituents of the body itself. We may, therefore, consider that which is rejected is only the dross which has gradually become unfitted for the functions of life in the different organs of the body.

The essence of the ingested nutriment passes from the digestive canal into the circulation, during which process it is transformed into blood, and thus conveyed to the several organs of the body. There it undergoes certain alterations, and returns as waste material into the venous blood, from which certain organs secrete and discharge it externally.

§ 2. The first change, therefore, which nutriment undergoes, after leaving the alimentary canal, is sanguification. The aggregate of the changes which solid and liquid foods undergo up to sanguification is called digestion. The various organs of the body which unitedly produce these changes are termed by physiologists the digestive organs.

From the mouth, into which the saliva is poured by a number of glands through corresponding ducts, the aliment descends into the stomach. In the coats of the stomach are glands, smaller and simpler in construction, but far more numerous than the salivary glands, and which during the process of digestion secrete a peculiar fluid, termed gastric juice. Next after the stomach come the small intestines, into which the liver and pancreas, two large glandular organs, pour their secretions,—the former the bile, the latter a fluid somewhat similar to saliva. In the coats of the intestines, also, are numerous small glands supplying the intestinal juice. The large intestines follow, the lowermost, a tenth part of which is called the rectum, terminating in the anus.

Besides the secretions enumerated above, there is found a considerable quantity of mucus throughout the whole intestinal canal. This mucus is materially different in different places, owing to the admixtures which it receives in the several parts of the canal.

Saliva, gastric juice, bile, pancreatic and intestinal juice, combined with mucus, are themselves products of the blood; from which, having been elaborated by various glandular organs, they flow, as before stated, into the digestive canal. Thus do the fluid combinations, which have themselves been furnished by the blood, contribute in return to the accomplishment of all those transformations of the nutriment which are necessary for sanguification.

§ 3. **The Alimentary Principles.**—In order to understand these various alterations, it is necessary to make ourselves acquainted with the constituent parts of the nutriment we employ. Let us imagine, for instance, a kind of aliment so compounded that it alone shall be sufficient to maintain life. Nature furnishes such an example in milk. This article contains salts, sugar, fat, and a substance very nearly resembling albumen or the white of egg, which is the principal constituent of cheese, and is hence called caseine.

These four principles constitute by far the greater proportion of all nutritious aliment. I say the greater proportion, not the whole; for either fat or sugar may be absent singly in nutritious food, but not both together. Salts, fat, and albumen, or salts, sugar, and albumen, are three components which together are absolutely necessary for the nutrition of the body. They are examples of three groups of alimentary substances, which represent the essential part of all solid and liquid food. To express these groups in more general terms, we have—

1. The inorganic.
2. The organic destitute of nitrogen.
3. The organic possessing nitrogen.

The essential distinction between these three classes, lies in the particular nature of their composition.

The chemist means by an element, a substance which he cannot decompose into any other substances manifesting, abstracted from form and colour, any essential differences. The more important elements of nutriment are—

Potassium.
Sodium.
Calcium.
Magnesium.
Iron.
Fluorine.
Chlorine.
Phosphorus.
Sulphur.
Oxygen.
Hydrogen.
Carbon.
Nitrogen.

Technical names by which it will be sufficient for the unprofessional reader to understand as many substances differing in chemical properties, and therefore denoted by the chemist by a distinctive nomenclature.

The seven elements from potassium to chlorine belong principally to the mineral kingdom; they compose the inorganic aliments,—that is to say, those which exist without any mediate or immediate intervention of living beings, as, for instance, common salt. The instruments of living beings are called organs; and all those substances are called organic, the production of which depends upon the mediate or immediate activity of plants or animals; for example, sugar and alcohol are organic substances.

Nitrogen, carbon, and hydrogen are to be found in all living bodies, whilst entirely absent in many minerals. Therefore they may be denominated, in a stricter sense, organic elements. It is true they appear also in the inorganic world, just as inorganic elements appear also in the organic.

Intermediate between these two groups are oxygen, phosphorus, and sulphur, being nearly as much organic as inorganic elements.

§ 4. There are combinations of two inorganic elements in our nutriment; amongst these common salt, which consists of sodium and chlorine, holds the principal place. A combination very similar to common salt is that of chlorine and potassium, the latter of which represents the chief element of potash. I shall hereafter speak of common salt and chloride of potassium, under the appellation of compounds of chlorine. Both are distinguished by their free solubility in water.

To these combinations, each consisting of two elements, fluoride of calcium may be added, which is to be found in very minute quantities in wheat, in milk, and in blood, and is known to most readers as fluor-spar. It is composed of fluorine and calcium. Water dissolves it only at a high temperature, and even then very sparingly.

It may seem strange that common salt is not called a salt by chemists; the salts of chemists are even not similar to common salt in taste. Therefore, as I mentioned before, salts are only an example of the class of inorganic elements. In chemical language, a salt is a combination which does not consist of two elements, but of a combination of two parts, each containing two elements.

The number of salts is exceedingly large. In treating on the subject of food, it will only be important to refer to the oxy-salts; these consist of different elements of a metal forming, with a little oxygen, a base called an alkali, and of a non-metallic substance, with a large quantity of oxygen, forming an acid.

Almost all bases have a corrosive taste, like lime; almost all acids a sour one, as sulphuric acid; but this is not an essential quality either of bases or acids. A really significant characteristic of bases is their attraction for acids, and of acids their tendency to unite with bases. These duplex combinations of bases with acids constitute salts. The matter which is commonly employed as a test of both acids and alkalies is litmus, which is a blue pigment, prepared from a hard, granulated, grayish-white plant, belonging to the class of lichens, which, under the name of Swedish moss, is imported principally from Sweden. Acids turn the litmus red, while bases or alkalies restore its natural colour. The general reader may at any time aid his imagination by thinking of lime as the representative of the bases, sulphuric acid of the acids.

If in the combination of a base and an acid the base predominates in quantity, therefore communicating to the compound its peculiar properties, the salt is called basic, and acid if the acid have the preponderance; if neither predominates, the salt is called a neutral salt.

The bases of the salts of our nutriment are constituted out of the first five elements, which I called above, in a stricter sense, the inorganic. They are all metals, and in forming bases they combine with a small quantity of oxygen. I pass now briefly to enumerate these bases.

The combination of potassium with oxygen is potash; soda is composed of sodium and oxygen, just as common salt is composed of sodium and chlorine; soda is often elicited from common salt by the introduction of oxygen, which expels the chlorine. Potassa and soda are called alkalies in a stricter sense; they readily dissolve in water. Calcium with oxygen constitute lime; and magnesia, a substance very similar to lime, is formed from oxygen and magnesium. Magnesia is the base of the well-known medicine, carbonate of magnesia. For the future I shall include lime and magnesia under the common name of earths; they differ from alkalies principally in being much less soluble in water, and in having a slighter affinity with acids.

Iron combined with a higher proportion of oxygen than that which with calcium forms lime, is called oxide of iron, which, in combination with water, produces iron-rust. It differs from the earths and alkalies in being insoluble in water.

All the above-named bases appear in aliment, only in union with acids, forming salts. The most important acids are constituted of those elements which I have called intermediate between inorganic and organic substances.

Sulphur forms, with a large proportion of oxygen, sulphuric acid, generally known by the name of oil of vitriol. Phosphorus, combined with still more of oxygen than sulphuric acid contains, is called phosphoric acid, which constitutes with lime the solid material of bones. To those may be added carbonic acid, which produces the sparkling bubbles of champagne, and is a compound of carbon with a smaller proportion of oxygen than is found in sulphuric acid.

The names chiefly of acids are employed in the naming of the salts. All combinations, for instance, of sulphuric acid are called *sulphuric salts* or *sulphates*. But sometimes salts are named from their constituent alkalies; all combinations of potash with acids, for example, are called *salts of potash*.

The alkalies, potash, and soda appear in our food, compounded with the three above-mentioned acids. They form neutral salts with sulphuric acid, sometimes acid salts with carbonic acid, and always basic salts with phosphoric acid. Of these three classes, the last-mentioned enter by far the most largely into the composition of our food.

Amongst the earthy salts, those formed with phosphoric acid again prevail. These are always basic, and can only be dissolved with difficulty in pure water, but become easily soluble if a little acid be added.

The sulphate of magnesia, known to everybody as Epsom salts, is soluble in water; but sulphate of lime or gypsum can only be dissolved with great difficulty.

Finally, the oxide of iron enters into our food in combination with phosphoric acid; and the salt thus formed, though insoluble in water, is dissolved by acids with tolerable ease.

The inorganic principles of nutriment are therefore as follows:—Compounds of chlorine and alkaline salts, both soluble in water; earthy salts and phosphates of iron, which dissolve in water with difficulty or not at all.

§ 5. The organic alimentary substances without nitrogen are in part compounds of carbon, hydrogen, and oxygen, which are capable of being transformed into fat, and we therefore call them *constituents of fat*. In part they consist of different kinds of fat itself, all of which are compounded of the same three elements.

In most constituents of fat, these elements are combined in the same relative proportions; and two of them, hydrogen and oxygen, in the same as that in which they are found in water.

All fatty substances contain the same proportion of oxygen, and proportions of carbon and hydrogen mutually equal, though varying in different kinds of fat. In comparison with hydrogen, fat itself contains much less oxygen than water or the constituents of fat.

The most important constituents of fat are starch, gum, and sugar. We shall often include these under the name of *starchy substances*. Starch is only soluble in boiling water, but the other two easily in cold.

Of the fatty substances we must here mention *oleine*, *margarine*, and *stearine*. Oleine is the chief component of all oils, and denotes their characteristic part, which slowly coagulates by cold. Besides oleine, oils contain a fat which hardens more readily, and may be obtained in crystals, glittering like mother-of-pearl. On this account, and not because it is actually found in mother-of-pearl, it is called mother-of-pearl fat, or margarine. Stearine is the firmest of all fats. It is the principal substance in the fat of mutton and beef, where it is combined with margarine and oleine. Stearine candles contain stearine and margarine.

While most constituents of fat are identically composed, sugar only containing more hydrogen and oxygen than the others, there is in oleine, with the same quantity of oxygen, more carbon and hydrogen than in stearine, and in stearine more than in margarine.

The above-named fatty substances are not soluble in water, and cannot as such be united with other substances in soluble combinations. As though saturated in themselves—that is to say, without any inclination to combine with other substances, and, so to speak, standing impartially between acids and bases—we may call them *neutral fats*, just as the salts in which acids and bases are in equilibrium are termed neutral salts. By the admixture of alkalies, neutral fats are separated into two substances, one of which is called the sweet principle of oil, or *glycerine*, a substance compounded of carbon, hydrogen, and oxygen; the other, and by far the greater part, is a *fatty acid*, which combines with the alkalies to form a *soap*. Thus oleine yields oleic acid; stearine, stearic acid; and margarine, margaric acid. As glycerine, which has been separated from neutral fats by potash or soda, is of the same composition, from whatever fat it is extracted, it follows that the remaining acids retain the same proportion of carbon and hydrogen, as the primitive neutral fats; that is to say, oleic acid contains more carbon and hydrogen than stearic acid, and stearic acid more than margaric acid.

The compounds of fatty acids with potash are called potash-soaps; and those of soda and fatty acids, soda-soaps. Soaps, therefore, may be regarded as analogous to salts, the acids being an inorganic substance destitute of nitrogen, the basis an inorganic body.

§ 6. Another group of *organic alimentary principles* are those *containing nitrogen*, which are compounded of a greater number of elements than fat and its constituents contain. Of these constituents of food, we have only to mention the albuminous substances. All albuminous aliments contain nitrogen, carbon, hydrogen, oxygen and sulphur, and most of them phosphorus also. The white of a hen's egg gave its name to these substances, which have been properly united into one group. The proportions of nitrogen, carbon, hydrogen, and oxygen, of which they chiefly consist, show a most surprising, if not complete agreement; recent chemical investigations having proved that, with respect to the four latter elements, their composition is almost identical. Before this, however, the great similarity of their properties had led to their being comprised under one general name. Four of them, the caseine of milk, the principle of the yolk of eggs, the gluten of grain, and the globuline in the crystalline lens, as well as the globules which float in the blood, are distinguished by not containing any phosphorus. The quantity of sulphur is different in these several substances, just as that of phosphorus is in those which contain this element. In the following list, the albuminous substances are given in order according to the quantity of sulphur they contain; those which possess the higher proportion being placed first:—The albumen of eggs, the albumen of blood, fibrine and globuline of blood—both of which contain an equal quantity of sulphur; the principle of the yolk of eggs, gluten, caseine, soluble vegetable albumen, coagulated vegetable albumen, and legumine. The largest proportion of phosphorus exists in legumine; the albumine of eggs stands next, which, however, contains scarcely a quarter of the phosphorus of the former; and last of all, fibrine and albumen of blood. The amount of phosphorus in soluble and coagulated vegetable albumen has not yet been determined; but the quantity of sulphur and phosphorus is always very small in comparison with that of the other elements.

Amongst the albuminous principles, soluble vegetable albumen, legumine, albumen of the blood, albumen of eggs, globuline and caseine are, when fresh, soluble in water; the principle of the yolk of eggs dissolves with great difficulty; coagulated vegetable albumen, gluten, and fibrine of the blood not at all. The different kinds of albumen, in a stricter sense, coagulate if boiled in water, as everybody has seen in hard-boiled eggs. The globuline of blood coagulates by warmth alone; legumine and caseine by acids in a warm temperature. We know how quickly milk curdles and turns sour in warm weather.

All albuminous principles, insoluble as well as soluble, are, in a coagulated state, dissolved at a somewhat higher temperature by a solution of potash, and are from this solution precipitated by acids in a solid form.

§ 7. **Digestion.**—After this brief description of the most important alimentary principles comprising our nutriment, we shall resume the account of digestion.

The whole of digestion is included under two grand processes. First, the alimentary principles must be dissolved, or very minutely divided; and secondly, if different from the constituents of blood, they must be transformed into these. Let us now see how these changes take place by the action of saliva, gastric juice, bile, pancreatic and intestinal juice, upon the compounds of chlorine, the salts, the constituents of fat, the fatty substances, and albuminous matter.

All fluids which flow to the digestive organs contain a relatively great quantity of water, at a temperature of 98° F. Common salt and chloride of potassium are easily dissolved in this water, as well as the phosphoric, sulphuric, and carbonic alkalies.

In the liquid of the gastric juice is a free acid. The earthy salts, therefore, which we described above as hardly or not at all soluble in pure water, but easily so in acid, are by this means reduced to a dissolved state.

Owing to the higher temperature peculiar to all the fluids of our body, a part of fluoride of calcium is dissolved; but the greater part of it, and of the oxide of iron, remains undissolved. This explains why the alvine evacuations always contain so much iron. Here also the gastric acid plays an important part, inasmuch as it dissolves a portion of the iron, which is thoroughly indispensable to the blood.

Starch by itself is not soluble in the water of the digestive fluids; but saliva, the mucus of the mouth, pancreatic and intestinal juice, have, in combination with each other, in a remarkable degree, the property of transmuting starch into gum, and gum into sugar. Thus, starch is not only indirectly dissolved, but is subjected in that process to such changes as render it capable of being assimilated with the substances of the blood; for sugar is transformed into lactic acid by the action of the bile; lactic acid into butyric acid while progressing through the alimentary canal; and butyric acid is the first link in the series of fatty principles which are found in living bodies. Oleic and margaric acid differ in their composition from butyric acid only by containing more carbon and hydrogen in proportion to their oxygen.

The last effect of digestion upon all the constituents of fat is transmutation into fat itself. Starch and gum are transformed into sugar, sugar into lactic acid, lactic acid into butyric acid, and butyric acid into other fatty substances.

Neutral fats are principally digested by the action of pancreatic juice, assisted by the bile. These fluids divide the fat into particles so small, as to be capable of easily penetrating through the membranes moistened by the bile. Another smaller portion of the fat is actually dissolved, for the carbonic alkali of the bile first effects a saponification of the fat, then the continuous action of the pancreatic juice transforms it into fatty acids and glycerine: thus stearic acid and glycerine arise from stearine, oleic acid and glycerine from oleine. The fatty acids combine with alkalies into soaps, which are soluble.

All the fluids of the digestive canal act as solvents upon the albuminous substances; and to this dissolving action almost all the components of these fluids contribute. It is especially so with the free acid of the gastric juice; in the next place, with the predominating alkali of saliva, bile, pancreatic, and intestinal juice; then with organic substances, water and the salts of all digestive juices. By the action of the acid of the gastric juice, the soluble albuminous substances are first coagulated; but they are again dissolved by degrees, by means of a power which the gastric acid exercises upon undissolved albuminous substances, supported by the alkalies of the intestinal and pancreatic juice. The most important agents in the dissolution of albuminous matter are, however, the organic components of the gastric and intestinal juices.

By the dissolving action of the digestive juices, and by the peristaltic grinding motion of the walls of the digestive canal, food is transmuted in the stomach into a pulp called *chyme*. This, by degrees, is rendered more liquid, until it becomes a thick, milky juice, which physiologists call *chyle*.

This chyle is essentially a mixture of dissolved compounds of chlorine, of salts, sugar not yet entirely transmuted into fat, of lactic and butyric acids, of finely divided and saponified fats, and of soluble albumen. Here, also, the latter may be regarded as representing the remaining class of albuminous substances; and this so much the more as these after-liquefactions have become, in the highest degree, similar in their properties to soluble albumen; but still they retain their original composition.

§ 8. **The Chyle.**—Thus the liquefied alimentary principles flow over the inner surfaces of the intestinal walls, in which are numerous vessels, long and narrow canals with thin walls, into which the greater part of this milky chyle exudes. These vessels are, therefore, called *lacteals*. Not only their walls, but also those of the blood-vessels, are permeable by liquids; and therefore a considerable part of the chyle also exudes into the blood-vessels of the intestines.

When digestion is nearly finished, the lacteals teem with a white milky juice, which owes its colour to the fat they have taken up; for if no fat has been digested, we find in these vessels only a clear, transparent juice, scarcely deserving the name of chyle.

The very numerous and smallest lacteals gradually unite themselves into larger trunks, which, at certain points, run very near each other, repeatedly widening and contracting, something like a string of beads, and pursuing irregular windings, held together by cellular tissue, and forming, as it were, lumps or knots, which have been improperly called intestinal glands.

The lacteal vessels, after having passed through these knots, by uniting in larger and larger trunks, form at length one duct. By the junction of this trunk with two vessels, which convey a white, watery fluid from other parts of the body, and are called *absorbents*, another canal is formed, which passes through the cavity of the abdomen and chest near the vertebral column, and is called the *thoracic duct;* through this the chyle flows into the blood.

The composition of the chyle, which has been taken up by the lacteals, differs very little from the liquid which, during digestion, is contained in the lower part of the small intestines. Before these vessels in their convolutions have become united into knots, the properties of their contents are almost entirely the same as they were in that part of the intestines from which they were taken. The quantity, however, of solid matter held in solution in the liquids varies; accordingly, the chyle contains more water in the lacteals than in the intestinal canal. This facilitates the transition of matter from the intestinal canal into the lacteals. The water in the latter has a great affinity to the substances which, in a dissolved or liquefied state, flow over the interior walls of the intestines. The chyle of a person fasting is more watery and thin than that of one who has had a plentiful meal.

Up to the formation of the above-mentioned knots, the lacteals commonly contain an alkaline solution of compounds of chlorine and salts, among which common salt and phosphate of soda predominate, with a certain quantity of sugar; also, if any amylaceous substances have been present in the food, neutral fats, as well as oleic and margaric soaps,—that is to say, compounds of oleic and margaric acid with soda and potash; and, lastly, albumen and fibrine.

The last-named substance is not yet quite identical with the proper fibrine of the blood, of which the characteristic property is that of spontaneously coagulating without the application of heat or acid when withdrawn from the living body. The fibrine of the chyle, which has in other respects the same properties, acquires this quality, only on its way from the intestinal canal to the blood-vessels, and after having left that part of the lacteals which is convoluted into knots.

In the lacteals also begins the development of a red colouring matter, which, besides nitrogen, carbon, hydrogen and oxygen, contains some iron. The quantity of the latter is as constant as it is small in proportion to that of the four first-named elements. This substance must necessarily be formed from one of the albuminous principles, and an iron salt of the chyle. It is the occasion of the light-red colour so often remarked in the superior part of the thoracic duct. This constituent of the chyle, containing iron and nitrogen, is called *colouring matter of the blood*, because blood possesses no other constituent of this colour.

How far the formation of blood has now advanced, will best be seen if I pass to the description of the blood itself.

§ 9. **The Blood.**—In the blood of man, vesicles are suspended containing a red substance, and white, granulated corpuscles. The former are called *coloured*, the latter *uncoloured blood globules*.

The fluid, in which the blood globules are continually in motion in the living body, is always impregnated with three different kinds of gas—oxygen, carbon and nitrogen. Apart from these gases, the blood consists of a solution of salts, albuminous substances, fat and sugar. When withdrawn from the veins or arteries, the blood deposits a red clot, leaving a yellowish liquid. The former contains principally the fibrine and coloured matter of the blood; the latter is albumen and salts. Fat is equally distributed in both. This separation into clot and liquid arises from the property of fibrine to coagulate, as soon as the blood is removed from the influence of the living body. While coagulating, the fibrine incloses the blood globules, and therefore the clot retains the red colour. In the vessels of the living body, fibrine always exists in the dissolved state. This is in part effected by the salt and the predominance of alkali in the blood; but only in part, because the salts and alkalies are not able to keep the dissolved fibrine out of the body. The supposition may, therefore, be justified, that the fibrine leaves the blood and blood-vessels of the living body before it has become ripe for coagulation. Out of the body, fibrine undergoes this development in the blood itself, and coagulates, even where temperature, motion, and protection from the external air, have been maintained artificially as much as possible as it had been during life. I consider the oxygen contained in the blood itself the chief cause of this change.

The coloured globules consist of a white capsule, containing a red liquid; this capsule being of an albuminous substance, is so transparent that it becomes entirely invisible when the colouring matter has been washed out of the globules by a sufficient quantity of water. The red colouring matter, which is contained in the blood globules, besides several salts, fat and albumen, is invisible through its pellucid enclosure. Iron is the element which, in the colouring matter of the blood, is united with nitrogen, carbon, hydrogen and oxygen, just as sulphur or phosphorus are in the albuminous substances. Its presence is indispensable for the formation of the colouring matter; therefore is iron so efficacious in many diseases, when the blood contained in the finest vessels, and shining through the skin, has lost its colouring matter. This red pigment of the blood, when fresh, is soluble in water, and still more so in alkalies, which are even capable of dissolving it in a dry state. The alkali of the blood facilitates, therefore, the solution of the colouring matter.

No albuminous substance is so abundantly dissolved in the blood as real albumen, which, remaining in the liquor after its separation from the clot, coagulates only at the boiling-point, just like the white of an egg. Traces of caseine are found with the albumen in the blood.

Fresh blood manifests an alkaline action with litmus. This is to be attributed to the presence of a basic phosphate of soda. Amongst the salts of the blood, phosphate of soda, and acid carbonate of soda predominate. To these salts may be added the compound of potash with the same acids; besides the sulphates of soda and potash, the phosphates of lime, magnesia, and oxide of iron, are all salts, which are conveyed to the blood with the chyle.

In our own times chemists have succeeded in detecting fluoride of calcium among the constituents of the blood.

Just as of all other albuminous matters existing in the serum of the blood, albumen, strictly so called, is the most abundantly represented; so also common salt or chloride of sodium predominates among inorganic substances. Chloride of potassium is present in relatively smaller quantity.

Blood contains, if examined when taken quite fresh from the living body, oleine and margarine. But they are very rapidly decomposed into oleic and margaric soaps, by the influence of the albuminous substances and the carbonates of potash and soda in the blood. With them another fatty substance is also present, remarkable for the amount of nitrogen and phosphorus which it contains, and a second distinguished from most vegetable and animal fats by its phosphorus.

Analogous to the neutral fats, consisting only of oxygen, hydrogen, and carbon, we find a compound intermediate between fat and wax, containing less oxygen than the former, and incapable of being saponified, bearing the name of bile-fat, only because it had first been discovered in the bile.

Sugar is always found only in a small quantity in the blood. Before it reaches the circulation, it has been for the greatest part transformed into fat.

In order to give an idea of the proportionate quantity of the constituents of the blood in round numbers, I add the following summary review. A thousand parts of blood contain—

Fibrine	2
Blood globules	131
Albumen	71
Compound of chlorine and salts	5
Fat	2
Water	789
Total	1000

ORIGIN OF THE SOLID SUBSTANCES OF THE HUMAN BODY.

§ 10. The blood is conveyed from the heart to all parts of the body. The heart propels it, by regular contractions, into the vessels, which have also a regular pulsation, and are called *arteries*. These ramify in smaller and smaller vessels, which at length from their minute size are called *capillaries*, and pervade in very great number all the organs of our frame. By means of the arteries every part of the body receives arterial blood.

The dissolved substances of the blood pass everywhere through the walls of the capillaries, forming thus what is called the *juice of nutrition*. As the fluid from which crystals are precipitated is called mother-lye, so we may call this juice of nutrition mother-juice of the solid constituents of the body; for all vesicles or cellules, fibres, and formless deposits, composing the several solid parts or tissues, are formed from the substances dissolved in the juice of nutrition. This mother-juice at the same time owes its immediate origin to the blood.

§ 11. As the transudation of the blood is dependent on its 789-thousandths of water, all solid parts of our body are, and most of them very abundantly, saturated with this liquid. But the water of the blood never passes through the capillaries without salts.

A certain quantity of the inorganic constituents of the blood is therefore to be found in all tissues. Some of them are, however, remarkable for a very especial affinity to certain tissues. Thus, basic phosphate of lime predominates not only above all other inorganic substances, but also above all their other components. The affinity of common salt to the cartilages is equally conspicuous. The muscles, on the other hand, contain an equally large portion of chloride of potassium, the quantity of common salt being but small. Thus, while the blood contains much more common salt than chloride of potassium, the muscles possess much more of the latter than of the former.

Fluoride of calcium is another inorganic constituent, which, whilst contained in the blood only in a small quantity, forms a necessary material for certain tissues. Bones and teeth regularly attract this substance from the blood. Herein also we may recognise one of those peculiar affinities of tissues to certain inorganic substances of the blood.

Carbonate of lime, or chalk, which of itself is insoluble in water, has not yet been discovered in the blood; but it is possible that it may pass as such through the circulation into the bones; for the carbonic acid and chloride of potassium of the blood have the power of keeping small quantities of carbonate of lime in a dissolved state; and one part of the carbonate of lime is formed out of the sulphate of lime, which reaches the blood with the water and other nutriments we take. This sulphate of lime is decomposed with carbonate of soda, so as to form sulphate of soda and carbonate of lime. This new compound is a characteristic constituent of the bones.

§ 12. With a small quantity of most of the inorganic compounds in the juice of nutriment, a part also of the albumen of the blood passes into all tissues.

But certain laws of affinity prevail also amongst the albuminous substances, which determine their appearance in a regular way. Thus the crystalline lens of the eye appropriates the globuline of the blood, the walls of the blood-vessels caseine, and the muscular tissue fibrine.

It is true the latter is not entirely identical with the fibrine of the blood; for it is not in the muscles in a dissolved state, but forms fibres, which are characteristic of flesh. And yet this fibrine of the muscles is more easily dissolved in water containing a few drops of hydrochloric acid than coagulated fibrine of the blood.

The influence of these laws of affinity is still more extensive with regard to thosq tissues which contain modified albuminous substances. To these belong *horn*, *gelatine*, and *the substance of the fibrous tissues.*

Horn is composed of nitrogen, carbon, hydrogen, and oxygen in proportions altogether similar to those of the albuminous substances. It covers the outer surfaces, it lines the walls of all cavities of the body; for the epidermis, nails, hair, the coating of the mucous membranes, lining the cavities of the intestines, the windpipe, mouth, and other interior parts of our body, consist of horny substances.

But though these parts, so different externally, are all called horny substances, on account of their affinity in composition with the horns of cattle, they are by no means identical; for, apart from the differences of their qualities, which certainly are not very considerable, they contain certain quantities of sulphur, which element, besides nitrogen, carbon, hydrogen, and oxygen, is to be found in all of them. The smallest quantity of sulphur is contained in the epidermis, and the coating of the mucous membranes; the nails contain more, the hair most. The two latter are with very great difficulty soluble in acetic acid. All horny substances agree with each other and with the albuminous substances in their solubility in potash, from which solution they are precipitated by acids.

We have to distinguish two kinds of gelatine: the one is prepared from the cartilages, the other from the bones.

Bone-gelatine is obtained by boiling bones in water. A saturated hot solution, which has been thus prepared, coagulates, when cooling, into a thick gelatine, which swells by the addition of cold water, and is dissolved again when boiled. In short, this substance is the well-known glue, which plays such an important part in the ordinary affairs of life; it is the same substance, better known as jelly, into which veal broth coagulates in cooling. But gelatine is not as such contained in the bones; it is produced by a slight transmutation, which this organic basis of the bones undergoes in boiling. Therefore bones are called a gelatine-yielding-tissue, which appellation is justly extended to many other component parts of our body; that is to say, to those fibres which, accumulated in bundles, invest most instruments of our body, and connect them with each other. For the last-mentioned property they are sometimes called binding tissues, though generally known as cellular. The stratum of the skin beneath the epidermis, the exterior covering of the lungs, of the intestines, of the muscles, of the nerves, of the bones, and of many other organs, consist for the greatest part of fibres, which, as well as the bones themselves, yield gelatine when boiled. The bones furnish a clear evidence of the affinity of the gelatinous tissues with phosphate of lime.

Nitrogen, carbon, hydrogen, and oxygen, with a very small quantity of sulphur, compose the bone-gelatine. I mentioned before that it is soluble in hot water; and I will only add its important property of not being precipitated from this solution by acetic acid.

Similarly to the bones, the cartilages yield, when boiled for a length of time, a peculiar gelatine, called gelatine of cartilage. This contains the same elements as the bone-gelatine, only in other proportions. While it agrees with the latter in stiffening to a jelly when the hot solution cools, it is the distinctive character of gelatine of cartilage, that strong acid produces a precipitation from a solution of it in water. I refer here again to the above-mentioned affinity of the tissue yielding gelatine of cartilage with common salt.

Whilst horn and gelatine possess an essential similarity in their composition to the albuminous substances of the blood, by containing sulphur, the elastic fibres are without this ingredient. But the latter still contain nitrogen, carbon, hydrogen, and oxygen, in such a proportion as to remind us directly of the albuminous substances in spite of this difference. Their absolute insolubility in water, as well as their resistance to acetic acid and potash, prove, however, that with respect to their properties they deviate the farthest from the albuminous substances. In these dissolving media they keep for days entirely undissolved.

Elastic fibres are found in an abundant quantity in the ligaments called vertebræ, which unite together the different bones of the spine; besides being found in the lungs, the walls of the arteries, and isolated in many other parts of the body.

That horn, gelatine, and the substance of the elastic fibres, are justly to be regarded as modified albuminous substances, is proved by the fact, that, with the exception of a very small quantity of fat containing nitrogen and phosphorus, no other compounds of nitrogen are present in the blood than the albuminous matters, which also are the only ones that contain sulphur. Horny substances and gelatine, both of which contain sulphur, can thus only have their origin in the albuminous principles of the blood. Perhaps it might be suggested, that the fat of the blood, which contains nitrogen, may produce the substance of the elastic fibres; but the quantity of this fat is much too small for the considerable quantity of elastic fibres in our body to be derived from it. The conclusion that the albuminous compounds are the only originating source of the horny substances, gelatine and the elastic fibres, is rendered unquestionable by the fact, that none of these substances are found as such in the blood.

§ 13. In fresh tissues, fatty substances are only present in the form of neutral fats, as oleine and margarine.

There is scarcely any part of the body from which these neutral fats are entirely absent. There is, however, very little fat in the lungs, and less in the teeth. It exists in great abundance under the skin; in the bones as marrow; in the mesentery, by which the intestines in the abdominal cavity are, as it were, suspended; in the orbit of the eye; and in the female breasts. The smoothness and roundness of the forms of females and children are chiefly attributable to the layers of fat, which cause the soft convexities of their skin. This fat is much less abundant under the skin of men; and the forms, therefore, of their bones and muscles are much more strongly defined.

Oleine and margarine are mingled in very different proportions in different parts of the body. I mentioned above, that margarine coagulates more readily than oleine. It follows, that the greater the predominance of oleine and margarine in any part of our body, the greater also will be the lubricity and fluidity of the fat; as, for instance, in the marrow of the bones and in the fat under the skin. The firmer fat again, which, for instance, surrounds the kidneys, contains more margarine than oleine.

We find the bile-fat of the blood unchanged in the brain; but the latter contains besides this also oleine, margarine, and another kind of fat, in which carbon, hydrogen, and oxygen are combined with nitrogen and phosphorus. Without this peculiar fat the brain cannot exist. It is remarkable that this brain-fat has been detected not only in the blood, but also in the yolk of eggs.

§ 14. Sugar is a regular constituent of the liver; the muscles contain also a peculiar kind of sugar, called sugar of the muscles. Lactic acid, a substance soluble in water, and compounded of carbon, hydrogen, and oxygen, exactly in the same proportion as in sugar of grapes, is found in the muscles in considerable quantities. In the brief description of digestion we saw that, by the influence of the bile, lactic acid is formed from sugar. It is more than probable that in the muscles also lactic acid is produced from their peculiar sugar; in short, the constituents of fat are also present in the different tissues, though in a very small quantity.

ON SECRETION.

§ 15. **Organs of Secretion.**—The sum of the processes which I have described in a former section, in order to explain the origin of the solid constituents of our body, is designated by physiologists as nutrition in the strictest sense. Not all matters, however, which transude through the capillaries from the blood are to be considered as having a direct share in the origination of the solid constituents. A very great proportion of the transuded matters do not contribute to the nutrition of the tissues, but remain as a liquid, which, having been attracted or prepared by certain organs from the blood, is collected into receptacles, and out of these discharged into certain cavities of the body, or altogether out of it. These receptacles are often simply canals, called secretory ducts of the organs; whilst the organs themselves are called glands. In other cases the secretory ducts lead, before they discharge the liquid, into wider reservoirs, called bladders. Thus we have a seminal bladder, a gall bladder, and an urinary bladder.

The fluids, which are attracted and collected from the blood by the glands, are in some respects of a special and immediate use in relation to the body, by assisting the functions of reproduction and digestion. All fluids which co-operate for these two essential functions, in preserving the species and the individual, are included under the general head of secretions. In all secretory fluids there is contained more or less water, which is a necessary condition of transudation generally.

§ 16. I begin with the ovum, not only on account of its importance in the preservation of the species, but because, next to the tissues, it is the firmest of the products of secretion. It forms, therefore, a kind of transition from the tissues themselves to the secretions. As the human ovum, in the earliest state of its development, can only be perceived by a high magnifying power, its investigation has been incomplete. We know certainly only this, that it consists of an albuminous substance, combined with oleine, margarine, brain-fat containing phosphorus, bile-fat, sugar, and the inorganic constituents of the blood.

§ 17. The seminal fluid can also be subjected only to a very imperfect analysis; but its chief constituent, the seminal principle (spermatine), is, in its essential properties, so nearly analogous to albuminous substances, that we may, without hesitation, classify it with them. Should future investigations confirm the slight distinction already observed, the seminal principle will still be proved to be a compound very similar to the albuminous substances; but it is not real albumen, as it does not coagulate by boiling. The seminal fluid contains, moreover, some true albumen combined with soda. Some fat and inorganic substances are also contained in the seminal fluid; but their properties and proportionate quantities have not been accurately investigated.

§ 18. An albuminous compound, which as such is found in the blood, though in small quantity, is abundantly collected towards the end of pregnancy and after confinement in the breast or lacteal gland of the female. It is the caseine, which, as contained in milk, forms an essential alimentary principle for the infant.

Caseine is the substance which coagulates at the surface of boiling milk, in the form of folded, wrinkled membranes, which as often as they are taken off are succeeded by others. It is completely and rapidly separated in thick flakes, if milk, which when fresh is alkaline, is boiled with an acid—for instance, with acetic acid. In this way milk is separated into a firm part, which contains, besides caseine, a great quantity of fat; and into a liquid, in which are sugar of milk, the rest of the milk-fat or butter, certain inorganic substances, and the acid which has been added; this last liquid represents the well-known whey.

The sugar of milk is a constituent of fat, like the sugar of grapes, into which the former can easily be transformed by acids. Sugar of milk differs from the sugar of grapes in being incapable of venous fermentation by the addition of yeast. This fermentation consists in the transmutation of sugar of grapes into spirit of wine and carbonic acid; but as acids transform sugar of milk into sugar of grapes, the former also is mediately fermentable. Sugar of milk is soluble in water, and consists, like lactic acid, of carbon, hydrogen, and oxygen, in the same proportions as sugar of grapes.

It is peculiar to sugar of milk, that its sweet taste is very slight. Here also we see, as formerly, when speaking of acids and salts, that taste is a very deceptive test of chemical distinctions. As sugar of grapes is found in the chyle and blood, and corresponds in its composition and properties very nearly with sugar of milk, the latter is therefore to be derived from the sugar of grapes, and also from the amylaceous substances of our nutriment, which are transformable into sugar.

When we speak in ordinary life of butter, this has a much wider signification than chemists attach to the name of butter-fats, or butyrine. In the latter sense, we understand by it a neutral fat—fluid at ordinary temperatures—which, when combined with alkalies, produces a soap, the acid of which, when free, is very volatile, and possesses a strong acute smell and taste of butter. This acid is, therefore, called butyric; but in butter, butyrine is mixed with oleine and margarine; and by the saponification of butter, we not only obtain alkali-salts of oleic, margaric, and butyric acids, but also of three other fatty acids, which, like butyric acid, are remarkable for their volatility and pungent smell. I call them caseic, sudoric, and capric acids (capronic, caprylic, and caprinic acids of other authors).

While butyric acid, with other fatty acids found in our bodies compounded with glycerine or alkalies, contains in proportion to oxygen the least quantity of carbon and hydrogen, the latter two elements are more abundantly represented in the three other volatile acids of the butter, namely, caseic, sudoric, and capric acids, the first containing the smaller quantities.

As milk contains, among its inorganic constituents, common salt and chloride of potassium, which is similar to it, as well as the compounds of potash, lime, magnesia, and oxide of iron, with phosphoric acid, it is apparent that the most important base, and the most important acids, together with the compounds of chlorine of the blood, are represented in milk; that is to say, all the inorganic substances to which different tissues possess a distinct and peculiar affinity, are there represented.

§ 19. Saliva, gastric juice, bile, pancreatic and intestinal juice, have already been discussed, according to their several parts in the digestive process. I have briefly to review them here also, as they take an important place among the substances transuding from the blood, through the walls of the capillaries. An albuminous compound which, from its presence in saliva, has been called the saliva principle (ptyaline), oleic and margaric alkalies, bile-fat, a fat containing phosphorus, and all the inorganic substances which I have specified as contained in the blood, clearly bespeak the origin of saliva, which appears in the mouth mixed with mucus.

In the saliva, as it flows from the secretory canals of the salivary glands, alkali predominates. Why, at the same time, the fluids of the mouth are so seldom found acid, is not yet thoroughly known, as, according to the most recent researches, even pure mucus of the mouth, unmixed with saliva, appears to possess alkaline properties.

§ 20. Gastric juice, furnished by the small glands of the stomach, also contains an organic substance, which, like the albuminous matters, is neither alkaline nor acid, but consists of nitrogen, carbon, hydrogen and oxygen, and is, at all events, closely allied with the albuminous matters, though it differs from them in some less essential properties. As it cannot be denied that this combination has a highly important influence in dissolving the albuminous substances, the digestion of which is one of the first conditions of the formation of blood; it has, therefore, not improperly been called, *par eminence*, the digestive principle, or pepsin. The digestive principle is, however, very vigorously supported in its dissolving action by a free acid, to which the gastric juice owes the property of reddening litmus. This is to be considered, according to the most recent investigations, as hydrochloric acid—an inorganic acid consisting of chlorine and hydrogen.

Among the inorganic substances of gastric juice, we have besides to mention the compounds of chlorine with sodium and potassium, with calcium, magnesium, and iron, and with the phosphoric salts.

§ 21. In the secretion of the liver, there are two peculiar organic acids, one of which, containing only nitrogen, carbon, hydrogen, and oxygen, is called *cholic acid;* the other, which, besides the four elements mentioned, contains a very inconsiderable quantity of sulphur, I may call sulphurized cholic acid. Apart from the liver, no trace of these acids is to be found in the blood. They are therefore not elaborated in the general circulation, but by the action of the liver.

A sweetish-bitter taste is not only peculiar to these acids, but also to their combinations with sodium. In the latter form they are soluble in water.

The combination of both these acids leaves no doubt that the albuminous substances of the blood are essential to their formation. Oleine, margarine, and gall-fat, accompany the combinations of potash with cholic acid and sulphureous cholic acid.

The bile owes its yellowish-green colour, sometimes inclining to brown and sometimes to green, to several organic colouring matters containing nitrogen; and its alkaline character to phosphate of soda, a salt in which the alkaline ingredient predominates. The other inorganic substances are common salt, chloride of potassium, carbonic alkalies, and the phosphoric salts of lime, of magnesia, and of oxide of iron.

§ 22. The pancreatic juice is a fluid containing so much albumen, that it coagulates by heat almost as completely as the white of eggs itself. The alkaline property of this secretion, certainly, greatly contributes to its carrying with it so much albumen from the blood into the cells of the pancreas. The albumen of the pancreatic juice, however, does not entirely correspond to that of the blood. Both are precipitated by alcohol from their solution in water; but if we dry the albumen of the blood which has been precipitated by the alcohol, we cannot dissolve it again in water; while the albumen of the pancreatic juice is even then soluble.

Besides margarine, and some other organic substances which have been very imperfectly examined, because of the difficulty of procuring pure pancreatic juice, we find in this liquid common salt, chloride of potassium, phosphoric, carbonic, and sulphuric alkalies, and lime combined with carbonic and phosphoric acids.

§ 23. With all digestive fluids is mixed a certain quantity of mucus, which is alkaline in the mouth, and is said to be neither acid nor alkaline in the empty stomach. In the intestines this mucus is not only mixed with all the above-mentioned digestive fluids, saliva, gastric juice, bile and pancreatic juice, but contains also a peculiar secretion attracted from the blood by certain small glands in the walls of the intestines. These glands, however, are small, and the quantity of their secretion is scanty; but the quantity of the other digestive fluids mixed with it is abundant. Therefore we know of this intestinal juice nothing more than that it possesses alkaline properties.

Mucus contains, first, a peculiar element of which little is known, but from which it derives its property of cohering in threads; secondly, a number of horny cellules, detached from the exterior coating of the intestinal canal; and finally, a combination of carbonate, phosphate, and sulphate of soda, phosphate and carbonate of lime, and oxide of iron.

ON EXCRETION.

§ 24. **Decomposition and Transition.**—It is a fundamental property of the organic substances of our body, that their combinations possess very little permanence. A perpetual process of transition from one state of being to another constitutes a grand circle, of which the nourishment of man himself forms but one little segment. The life of plants and animals is not only a direct result of this constant change of matter, but all organic life is a continuous process of alternate combination and decomposition, to which higher and lower influences, co-operating in essential harmony, contribute. What plants absorb from the soil and the air they transform into substances on which the herbivorous animals feed; and by the latter they are retransformed into animal food for the support of carnivorous classes, as well as for those which feed upon a mixed diet. To the latter class, man himself belongs. Then that which is given off in an uninterrupted series of various kinds of decomposition by men, animals, and plants, during life and after death, returns again into the air and soil as material for the growth of another generation of plants. Here again the process of transition recommences, and a perpetual and ceaseless revolution is pursued.

I repeat, that during life itself this decomposition takes place. In the very tissues a regressive metamorphosis, so to speak, has already begun; for the oxygen of the air, which we incessantly inhale, is conveyed to all parts of our body. And no element exerts a mightier influence in the formation and dissolution of organic combinations than oxygen. Exposed to the continual action of this element, which all kinds of vegetation are unceasingly giving forth into the atmosphere, no organic combination of our bodies can maintain its permanence. Albumen, gelatine, and fat, fibrine and sugar, all are gradually rearranged into compounds, containing at every step an increased quantity of oxygen. These revert from the tissues into the blood, from which they are attracted by certain glands, collected into receptacles, and at last ejected externally. This ejection is called excretion.

§ 24. **Connection of Excrementitious Bodies with the Tissues.**—I repeat, decomposition has already begun in the tissues; for what physiologists of a former age had rather conjectured than proved, has been triumphantly demonstrated by more recent investigations, and it is now known that the constituents of the tissues gradually deposit a sediment, which, being unfit for the functions of the organs in which it accumulates, is conveyed back to the blood, in order to be excreted from it.

The most important substances which are excreted, have in the course of physiological science been traced from the blood into the tissues. The blood contains urea, the vitreous humour of the eye also; carbonic acid is present in a large portion in the blood, and is likewise to be found in every solid part of our bodies; and carbonic acid and urea are the principal products of decomposition, which the lungs and kidneys abstract from the blood, in order to remove them as waste material from the body.

A process which ceases not even for a second, and in which one development is continually following another without any cessation, can evidently be marked at certain stages of the transformation only. Therefore we cannot make out in an uninterrupted chain the whole series of intermediate conditions through which the albuminous and adipose substances pass, before being wholly decomposed into those simple products, urea, carbonic acid, and water. But since, through the increasing number of investigators, aided by instruments of greater delicacy, more and more points of transition have been found in the series conducting from the constituents of the blood, through the tissues, to the excretions, we are able confidently to assert, that we are pursuing our investigations in the right direction.

We cannot at present draw any distinct limit between substances belonging to the development and those belonging to the tissues. But no greater praise can be bestowed upon the physiologist than that he breaks through the barrier by which it has too often been attempted to enclose certain parts of nature, and to blockade the understanding of man. The transitions of nature are numberless. The boundary-lines between the several classes of natural bodies lose their distinctness in proportion to the extent and depth of our scientific knowledge.

To the substances transitional between development and regressive transformation, belongs a combination consisting of nitrogen, carbon, hydrogen and oxygen, which is found in the juice of flesh, and which may be called the *flesh-principle*, or kreatine. It is not yet known what intermediate substances connect this principle with the albuminous compounds from which it originates; we only know, that by the mere presence of acids, which are never absent from the flesh, kreatine is transformed into an alkaline substance, which is to be found, not only in the flesh, but also in the urine. This substance may be called the flesh-basis, or kreatinine, and considered as decidedly an excrementitious body, which has passed into that stage in the tissues themselves; being formed from the albuminous matters, and having passed beyond the intermediate state of the kreatine. The acid peculiar to the flesh, technically called frosinic acid, which is to be found in the muscles associated with lactic acid, most probably belongs also to the products of regressive transformation, although it has not hitherto been discovered in any excretion, but only in the flesh itself.

Like the flesh-principle, so are the peculiar basis and acid of the flesh compounded of nitrogen, carbon, hydrogen, and oxygen. The flesh-principle is transformed into flesh-basis by the subtraction of water only. Flesh-acid is remarkable for containing a high proportion of oxygen. While the flesh-principle, as such, combines neither with bases nor acids, the flesh-basis unites, as its name indicates, with acids, and the flesh-acid with alkalies. Flesh-basis and flesh-acid are easily dissolved in cold water, the flesh-principle with more difficulty, requiring boiling water, which dissolves it in great abundance.

These illustrative examples may be sufficient to establish the general proposition, that the formation of the excrementitious bodies begins in the tissues themselves, and that the function of the excretive glands is mainly to attract and elaborate these substances from the body; for the products of the regressive metamorphosis pass from the tissues into the blood, and from the blood into the excretive organs.

§ 26. **Excreting Glands.**—If among these glands the most important place is ascribed to the respiratory organs, the conviction is founded upon the fact, that the functions of the lungs can least of all bear interruption without disturbing, or altogether destroying, the activities essential to life. That element in the surrounding atmosphere, therefore, which is absolutely necessary for respiration, may be called vital air. This vital air is the oxygen, which I have already denominated the mightiest agent in producing the metamorphosis of tissues.

The air we breathe is a combination of oxygen with a large proportion of nitrogen, a little aqueous vapour, and still less carbonic acid. While the oxygen at every inspiration enters the lungs in order to impart to the blood its proper composition, the carbonic acid of the atmosphere, on the other hand, originates from the breath given out at every expiration from the lungs of men and animals. Valuable researches have shown that this carbonic acid penetrates from the air into the leaves of plants, in order to supply the principal nutriment to these numberless green and flowering products of nature, which form such an essential condition of animal life: not as nutriment alone, for it is the vegetation of the earth which gradually decomposes the carbonic acid which it has absorbed, and whilst it keeps the carbon for the formation of its own tissues, exhales the greater part of the oxygen; the latter being called, as we have seen, and with the greatest propriety, the vital air of men and animals.

The carbonic acid which we breathe out is, as before mentioned, to be traced so far back as the tissues themselves; from these it penetrates into the capillaries in order to pass into certain canals, in which the blood flows in a direction opposite to that of the arteries. These canals are called *veins*, and are distinguished from the latter by not possessing pulsation.

The blood which the arteries have conveyed from the heart to the remotest organs of our body, having been changed by the substances which it has lost and by others which it has taken up during its course, flows through the veins back again to the heart, thus forming a true circulation. This circle is completed by the capillaries, which connect the arteries with the veins.

The venous blood contains an abundant quantity of carbonic acid; but this product of decomposition does not originate exclusively from the tissues, and pass therefrom into the veins, inasmuch as the arterial blood itself is already impregnated with a certain quantity of carbonic acid formed in this part of the circulation. The venous blood, however, contains more carbonic acid than the arterial, the former receiving an additional supply of this gas from the tissues.

Besides the great circulation from the heart, through the tissues, and back again to the heart, there exists also a small circulation of the blood; for all the blood of the veins, which flows into a special compartment of the heart, is propelled therefrom into the lungs, and returns from these into the heart, after having been changed in a peculiar way. The blood flowing from the heart to the lungs is dark red, even brown-red, containing but little of oxygen and much of carbonic acid; and this is the character of the venous blood in general. But in the lungs, to which an abundant quantity of oxygen is conveyed with the inhaled air, carbonic acid and aqueous vapour pass from the venous blood into this organ, and are compensated by the inhaled oxygen which transudes into these vessels. By this process the blood becomes light red, containing less carbonic acid and water than that of the veins. The blood thus transformed, returning from the lungs, is now called arterial, as it corresponds with that of the arteries. It is the blood of the arteries themselves, because it is conveyed to them by the heart, in order to permeate all tissues again with nutritious juice.

In its course from the heart through the tissues, the venous blood is therefore formed, which in the great circulation flows back again to the heart; and this blood, which in nourishing the tissues has undergone such important changes, is supplied again with oxygen while passing through the lungs, and thus adapted in return for the nutrition of the tissues; in short, it is transformed again into arterial blood.

As the ovum represents among the secretions a transition stage between these and the tissues, the lungs may be considered as organs, holding, in respect of their functions, an intermediate position between reception and separation. Carbonic acid and water are the excretions which they give out, and in return they take in oxygen. Without oxygen, no arterial blood; and without arterial blood, no nutrition. If the nutrition is interrupted, the functions of all tissues are deranged. The muscles cannot contract themselves, the nerves lose their irritability, the reasoning faculty of the brain is disturbed, if the blood ceases to furnish these organs with their peculiar combinations; and this latter process is dependent on the supply of oxygen; for all organic constituents of the blood are gradually transformed by oxygen. The albuminous and fatty substances have, without any exception, so great an affinity to oxygen, that they are gradually decomposed into combinations containing it; at every step of the process more oxygen. Oxygen passes also through the capillaries into the tissues themselves; therefore the venous blood contains less oxygen than the arterial, and the manifold decomposition becomes possible to which I have already stated the tissues are subjected.

We recognize in the flesh-principle, the flesh-basis, and the flesh-acid, a few of the intermediate stages through which the albuminous substances pass by the influence of oxygen. The last results of this influence are the urine-principle, or *urea*, carbonic acid, and water. The different fats are also transmuted into carbonic acid and water, with even greater readiness than albumen, as their greater amount of carbon and hydrogen facilitates their combustion with oxygen. Thus, we daily exhale through the lungs, in form of carbonic acid and water, about one-third part in weight of the nutriment we have taken. As this combustion depends upon nothing else than a combination of oxygen with other elements, it follows clearly, that the inhaled oxygen, the affinity of which acts slowly but without interruption, burns down entirely all the organic substances of the blood. For this process four or five days only are requisite.

This act of combustion in great part explains why the temperature of the human body continually exceeds that of the surrounding atmosphere. The difference between the temperature of the latter and of our own body is, in scientific language, designated as *proper heat*. This proper heat varies according to the temperature of the internal air, while the actual heat always remains the same. The average amount of the latter is 98° F., without fluctuating a single degree during health.

§ 27. Though a part of the albuminous matters of the blood is lost from the body with the exhaled air, in the form of carbonic acid and water, still the kidneys are the principal organs which withdraw the waste albuminous bodies from the blood; for the urine, which is excreted by the kidneys, collected in the bladder, and voided externally by the urethra, is a solution in which urea, uric acid, flesh-basis, and flesh-principle are contained; all being substances whose amount of nitrogen, carbon, hydrogen, and oxygen, evinces their origin from the albuminous substances.

The flesh-basis and flesh-principle I have already described. They are present in the urine, but in very small quantities. This excretion contains also, in a somewhat greater quantity, uric acid—a substance scantily soluble in cold water, which, however, is dissolved in the urine as a urate of soda. Urea is easily soluble in water, and is contained in the urine in the most abundant quantity.

Besides the uric acid, the human urine sometimes also contains some lactic and butyric acids, with another acid nitrogenized, and peculiar to the urine of herbivorous animals, which chemists call uric acid of horses, or hippuric acid, as having been first detected in the urine of those animals.

But none of these acids have been found in the urine in an uncombined state. The acid reaction, however, of this excretion, is produced by an inorganic salt, termed acid phosphate of soda, in which the acid predominates. The more important concomitants of this salt in the urine are common salt and alkaline sulphates; but chloride of potassium, and the phosphates of lime and magnesia, are also found in the urine, which sometimes also contains traces of iron and of fluoride of calcium.

The quantity of urine voided in twenty-four hours, amounts to about one-third of the weight of the nutriment taken in the same time.

§ 28. **Constituents of the Secretions.**—It is a very general popular belief, that the excrements are only formed from the undissolved remains of food. Though these constitute a not inconsiderable portion, it is quite a mistake to suppose that this excretion is not essentially mixed with other constituents, owing their origin to the blood; for how could we doubt that the capillaries, which exist in the intestinal walls in such abundance, would allow any substances to transude into the intestinal cavity, as this transudation is the indispensable condition of any transition of dissolved substances into these blood-vessels? All animal membranes, which are moistened on each side by different fluids, permit substances to pass through in such a manner, that the matters transuding from one side are replaced by those which similarly pass from the other. The excrements are also mixed with a proportion of digestive fluids, mucus, products of decomposition from the bile, horny cellules from the mucus coating of the intestines, and other substances, which, when once secreted, do not return again to the blood.

The undissolved remains of our nutriment, which form the excrements with the substances just mentioned, are in part the insoluble, or hardly soluble constituents of the food, as the elastic fibres of animal food, and the cellular principles of vegetable nutriments, of which we shall treat in detail hereafter. There will also be found in the excrements such aliments as of themselves are soluble in the digestive fluids, if the quantity of the latter has been too small in proportion to the nutriment to effect its solution. Thus, a very great variety exists in the composition of the organic constituents of the excrements.

Of the inorganic constituents of our food, the rectum discharges, more especially the earths, the lime and magnesia salts, together with a considerable quantity of iron, on which, as well as on the constituents of the bile, the colour of the excretions is principally dependent. The soluble salts of the alkalies are also to be found in these excretions, partly transuded from the capillaries of the intestines.

§ 29. **Excreting Powers of the Skin.**—Besides the lungs, the kidneys, and the rectum, the skin has to be mentioned as another most important organ of excretion. Not only do the capillaries of the skin keep up an uninterrupted discharge of carbonic acid, and take in oxygen in return; but this organ is also abundantly provided with small glands of two kind, excreting from the blood the perspiration and the sebaceous or greasy substance of the skin, which are therefore called sudoriferous and sebiperous glands.

The perspiration contains many regularly detached scales of the epidermis. Besides a small quantity of fat, several volatile organic acids, consisting only of carbon, hydrogen, and oxygen, are the principal constituents of the perspiration. The chemist calls these butyric, butyro-acetic, and formic acids, and classes them in one group as being in their composition very similar to the fatty acids, to which butyric acid belongs, also with respect to its other properties. These acids occasion the sourness of the perspired fluid. Common salt, chloride of potassium, sulphates and phosphates of the alkalies, and traces of phosphates of lime and iron, are also dissolved in the perspiration.

To the perspiration may be added the tears. These are continually secreted in a very small quantity by a gland situated in the external corner of the eye, underneath the skin. From hence they flow over the surface of the eyeball to the internal corner, where they are reabsorbed by an aperture in each eyelid, leading by a minute canal into the nasal cavity, to be excreted with the nasal mucus.

The tears are a very diluted solution of common salt, mixed with some detached cellules from the external coating of the eyeball.

The sebaceous matter of the skin is also a mixture of detached epidermic cellules with some other substances, of which fat and some salts are the principal components. It has, however, a different composition in different parts of the skin. The ear-wax, for example, is remarkable for a bitter yellow substance, soluble in spirits of wine, and for a portion of gall-fat.

§ 30. **External Excretions.**—Just as a part of the intestinal mucus is voided as an excrementitious matter, so the mucus of the other parts of our body—of the nose, wind-pipe, lungs, urinary ducts, and the several organs principally of women—is to be considered an excrementitious substance.

As a considerable part of the mucus is represented by *horny substances* which coat the mucous membranes, with these excretions may be included those parts of the hair and nails which, being cut off and growing again—as if the younger parts pushed the older parts upwards—form a regular part of the expenditure of the body. It is the same with the epidermis, which is continually scaling off.

The organic origin of all these horny substances is to be derived from the albuminous compounds, which are, by their transformation into the former, separated from the blood; one part of a tissue is thus directly lost without having passed again through the blood from which it originated.

ON HUNGER AND THIRST.

§ 31. **Principle of Reparation.**—I have mentioned in a previous section that one-third in weight of the food we take during twenty-four hours is lost with the urine, and another third with the air exhaled. The other third of the consumed aliments daily leaves our bodies in the form of excrements, perspiration, mucus, fat, tears, and detached horny matter.

It is evident that this does not mean an immediate excretion of alimentary principles as such; for, excepting the undissolved remains of food which the rectum expels with the excrements, there is no substance in our excretions which had not passed from the mouth through the blood to the tissues, and from these back again through the blood to the organs of excretion. Thus, for example, the carbonic acid and water which we exhale have once been fat or albumen, and the urea has nourished the tissues in form of an albuminous constituent of the blood, before the kidneys convey it as a useless sediment of the body to the expelling bladder.

This main result is not affected by the indirect mode of the excretion of our nutriment. The weight of a healthy grown-up person does not undergo any sensible alteration from one day to another; for as much as is subtracted from the body by excretion, is conveyed to it again by the food which is digested.

Thus experience teaches, when the total amount of excretion diminishes, the weight of food we take decreases also. If the proposition could also be transposed,—if it were true that with a diminished quantity of food, a proportionate diminution of the secretions succeeded, then we could learn the art of fasting, and the horse of the well-known tale would not have died the day before he promised to crown the hopes of his parsimonious master with the most brilliant realisation.

It is not, however, thus. Even when abstaining from all solid and liquid food, we exhale carbonic acid and water; the excretion of urine and excrements continue all the same, the hair and nails grow, and perspiration and mucus hourly subtract from the body its most essential constituents; and this abstinence, if continued, is only too soon followed by considerable diminution in the weight of our body.

Food only is able to obviate this decrease of weight; and as excretion takes place even if we take no food, it is less correct to say that we excrete again the aliments we have taken, than that the food restores what has been lost by the excretions. For carbonic acid, urea, salts, water; we take in exchange amylaceous and fatty matters, albumen, and inorganic substances. On this process of exchange, the metamorphosis of tissues hinges; the alimentary principles are, therefore, very often and quite correctly denominated the matters of reparation.

§ 32. **Effects of Inadequate Aliment.**—If the supply ceases while the expenditure continues, the composition of the tissue is immediately changed; and the blood, which receives aliment not only for the tissues, but also for itself, fails in a few days, or at the longest in a few weeks—for the oxygen we inhale wastes the blood where supplies are stopped. The constituents of the body continue as before to succumb to the influence of that mighty agent in the decomposition of organic matters.

The changes in composition produced in the blood and the tissues by a deficient supply can only be distinctly observed after some time. Then we first of all observe the fat wasting away: a proof that the fats are more accessible to the action of oxygen than the albuminous substances. Carbon and hydrogen are the elements which combine with oxygen the most readily; and upon this depends their remarkable combustibility.

The emaciation is therefore explained by the fact, that the fat substances surpass the albuminous in their quantity of carbon and hydrogen.

Next to the fats, those organs lose the most rapidly in weight which are remarkable for their great amount of albuminous substances. The muscles, the heart, the spleen, and the liver waste away.

From this speedy decomposition is excepted only one part of the human body, and that the part of which we should be least of all disposed to predicate a slow process of change; for, although the brain and the nerves consist almost exclusively of fat and albumen, two of the most mutable substances of our body, we know from investigation in cases of animals which have died of starvation, and of men who have succumbed to protracted diseases, that precisely these organs have suffered the least loss of weight. The reason of this is an unresolved enigma. I only see one probable explanation for this strange circumstance in the peculiar manner in which albumen and fat are combined in the brain and the nerves. If this combination, however, and its resistance to the influence of oxygen, cannot be sufficiently explained, we still find in this fact the best explanation of the late decay of the mental faculty, which we see so often flame up again with fallacious vivacity in the last moments of expiring life.

Slower than the fat and the muscles, but faster than the brain and the nerves, the bones, the cartilages, the skin, and the lungs waste away; including, in a word, all parts composed of gelatine, horn, and elastic fibres. These tissues owe their greater tenacity of existence to the difficulty with which they dissolve, which gives them greater power to resist the action of oxygen; for though the assertion of former chemists—that only dissolved bodies act upon each other—cannot be admitted without exceptions, yet there is scarcely any condition more favourable to chemical combination and decomposition than a state of solution.

§ 33. **Effects of Abstinence from Food.**—From a consideration of the intimate reciprocal action by which the blood is combined with the tissues, secretions, and excretions, the fact that with a failing supply the composition of the tissues still changes and the excretions continue, necessarily indicates an altered composition and diminished quantity of the blood. But while science endeavours to find the laws upon which this alteration in the composition of the blood is based, it has already ascertained a diminution of the colourless blood-globules in proportion to the coloured, and the decrease of the secretions after a protracted abstinence is an admitted fact. The activity of the glands of digestion, however, does not cease entirely; but the saliva, and the gastric and pancreatic juices, are decidedly diminished and altered; the saliva becomes viscid and saltish; while in men less semen, in women less milk, is secreted. Of the secretions, bile is present in the greatest proportion, though it also is diminished. This fact deserves so much the more attention, inasmuch as we have to consider the bile partly as a secretion and partly as an excretion.

It cannot surprise us that a diminution of the excretions should accompany the decay of the tissues, the impoverishment of the blood, and the impeded secretions. But although less and badly smelling air, scanty and stinking urine and perspiration, and a smaller quantity of excrements and mucus are voided, these excretions are just sufficiently abundant to prove clearly that they effect the decay of the tissues as a necessary consequence; there is in besides a smaller quantity of urine, in proportion to its contents of water, a greater quantity of urea excreted, which explains the considerable loss of albumen in the tissues.

The proper-heat diminishes during passing, and this completes the harmony existing between all these relative combinations; for when we exhale less carbonic acid, less carbon of the tissues is consumed; and by the smaller quantity of combustible substances which combine with oxygen, a decrease of the temperature produced in our bodies takes place.

A common tie unites matter, form, and function. The composition, the form, and the activity of the organs of our body form a chain, of which no link can be affected without a simultaneous alteration of the two others. There can likewise be no activity without continual transformation in the composition, without a perpetual becoming and ceasing to be. I therefore consider myself justified in deriving all life from the combination and decomposition of the matter of our body. The life is a change of matter.

During abstinence from solid and liquid food, as the composition is altered and the forms decay, the activity of all functions must necessarily deviate from that of the organs of a well-fed body. In the formation of the blood, the nutrition, the secretion and excretion, this deviation is easily to be understood, and has been, as far as necessary, examined in preceding paragraphs.

But the series of the altered functions is by no means thus closed. The muscle, lighter by having left its fat and albumen, appears a flabby flesh, which contracts slowly; the heart is inert, the number of the pulsations in a minute is considerably diminished; a sighing respiration takes place, frequent yawning, a hoarse voice, and languid movements, are all more or less direct consequences of the deficient nutrition of the muscles.

A bitter taste, often complained of by starving persons, comes from the bile, which is still pretty abundantly secreted, and passes from the intestines into the blood, by which it is carried to the nerves of the tongue. As the respiratory action is diminished, the combustion of that part of the bile transuding into the blood is less perfect than usual; so that a portion remains and acts upon the gustatory nerves.

In this condition, slight stimulants exercise a great effect. The light is painful, a slightly elevated sound is insupportable, and a touch excites peevishness. Perception is therefore distracted; and as memory also refuses its service, both sources of our faculty of judgment are exhausted; for what we have before met with or now meet induces the action of thought and judgment. But, in order to judge rightly, we must see clearly, hear distinctly, and feel without disturbance. During sleepless nights the starving person is tormented by eagerness, the powerful lever of so many passions. He who grasps at carrion and corpses, at the flesh of his friends, or of his own body, shows a wilder longing than the imagination even of poets has ventured to conceive.

There is another instinct by which the vigour of the mind is vanquished in a more melancholy way. Hunger desolates head and heart. Though the craving for nutriment may be lessened to a surprising degree during mental exertion, there exists nothing more hostile to the cheerfulness of an active, thoughtful mind, than the deprivation of liquid and solid food. To the starving man every pressure becomes an intolerable burden; for this reason, hunger has effected more revolutions than the ambition of disaffected subjects. It is not, then, the dictate of cupidity, or the claim of idleness, which prompts the belief in a natural human right to work and food,—a motive to the force of which Christian charity itself must sooner or later give way.

All honour, indeed, to the charity which in so many noble-minded people anticipates and mitigates the sternness of law. I am, indeed, far from retaliating the contumacious censure with which the asserters of this right are often met by their opponents. It is the part of wisdom and comprehensive tolerance fairly to balance the merits of all opinions, and to do justice to their respective beneficial result. So much the more, however, do I consider it a duty to oppose the cogent power of convincing facts, to the rigorous sentence which makes a human right dependent upon a human grace.

Cold and rigid, the muscles quivering in the paralyzed limbs; sighing, with troubled cloudy eyes, blunted sensation, and unsound judgment; the tortured wretch suffering the horrors of starvation struggles in agony, which often closes in a swoon, while sometimes a furious delirium will precede the final scene of death from exhaustion.

§ 35. **Effects of Hunger.**—I have thought it useful to describe the very extreme consequences of a deficient supply of nutriment, in order to explain by them the sensations which in general remind us to counteract the impoverishment of the blood, by a proper supply of food. The description of these sensations is the real science of hunger and thirst.

For, if the blood is deficient either in its composition, in quantity, in its constituent parts, or in the rapidity with which it circulates through the organs of our body, the tissues must be nourished by other means; so likewise the nerves, for their composition changes also with the combination of their mother-juices. But as the action, and therefore the sensation of a nerve are dependent on its composition, it follows that it must feel differently if deriving its nutriment from any other source.

If abstinence has lasted only a short time, all the phenomena occur which most people observe in themselves when awaking in the morning. The tongue is parched, *i.e.* the coat of horny cellules lining the mucous membrane is thickened, and this condensation goes as far as the stomach. The saliva and mucus contain less water, and are often of an unpleasant taste and of a bad smell, as may be observed in fasting people. Most persons, therefore, cannot eat anything in the morning until they have cleared their mouth and drunk some water. In feeble constitutions, and also in some strong ones, after a longer fast than usual, the quantity of blood present in the mucous membrane of the mouth and stomach is perceived by a vague, unpleasant sensation in the mouth and throat, or a pressure, tension, and emptiness in the stomach; rumbling in the belly, which is hollow and drawn in; yawning, a sensation of compression of the forehead up to headache and weakness, are the general indications of more constituents having been abstracted from the blood than is compatible with a sufficient nutrition of the nerves. Irritable persons become then so sensitive, that the least resistance, unexpectedly touching their bodies, or even an innocent word, is sufficient to put them out of humour. The total of all these phenomena, which are more or less conspicuous in different people, represents hunger.

If hunger remains for an unusually long time unallayed, the oppression of the stomach increases to pain and sickness. In autumn and winter the body becomes more sensible to cold, the general uneasiness disturbs the mental activity, unsteady thoughts are wasted in unquiet observation, and complete exhaustion is preceded by an excitement which only too often impels to unjustifiable acts.

§ 36. **Effects of Thirst.**—Many instances prove that hunger can be borne for several days before it causes death. If the fasting person drinks water, this time is considerably prolonged. While, on an average, man cannot live longer than a fortnight altogether without food; there was, in 1831, an instance at Toulouse of a convict who, preferring death by starvation to a public execution, survived for as many as sixty-three days on water alone.

Similar cases prove, that it is much more difficult to overcome thirst than hunger; and this is confirmed by daily experience. If it be alleged, on the other hand, that many people drink exceedingly seldom, and that females especially can do without drinking for many days together, neither must we forget that all food, even the driest, contains a great proportionate quantity of water.

Upon this reception of water into the system all depends. The blood and most of the tissues, with all secretions and excretions, contain an abundant quantity of water, as an indispensable condition of their right composition and proper action.

In the excretions from the skin and lungs, more than one-third of the weight of our food is daily lost in the form of water. To this a considerable quantity of water must be added besides, voided in the urine.

A deficient supply of water is, therefore, very soon felt; dry lips and cheeks, dryness of the tongue and throat, speedily betray the lack of that water of the mucus and saliva which ordinarily keeps the cavity of the mouth in a moist state. On the increase of thirst, the mucous membrane reddens and swells, and after a while the inflamed tongue cleaves to the roof of the mouth, and the glowing breath escapes in sighs; the skin burns, because the perspiration continually diminishes; the urine becomes acid, as it contains the usual salts and less water; the slackened muscles move the limbs listlessly, and without power; mere talking or deglutition becomes an effort; groaning and quick respirations accelerate the pulse. In the action of the brain and organs of the senses, there is the same irritation as in hunger. Restlessness and despair torment with the continual representation of water and other beverages, which would allay his craving. All liquids—sea-water, tincture for the teeth, even his own urine—are swallowed, or attempted to be swallowed, by thirst-distracted man, with passionate eagerness. If no relief is given, a violent inflammation of the mouth and throat supervenes, with all the symptoms of an acute fever; sometimes the inflammation causes even gangrene of the throat, a quick, sighing respiration, and a pulse proportionally more rapid; a loose, lolling tongue, a whispering delirium and rage, ending in death, if the sufferer does not expire senseless in a swoon.

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BOOK THE SECOND.

OF FOOD.

§ 37. **Definition of Alimentary Principles and Nutriment.**—From the blood are formed the tissues and the constituents of the secretions; to the blood the materials of the tissues return after having undergone a certain degree of decomposition, which renders them unfit for the peculiar functions of the different organs; and these products of decomposition are abstracted from the blood by the excretory glands, which expel them from the body.

The excretions diminish the weight of the body, and alter the nutrition of the tissues; their function depends upon their composition, and throughout a great division of the nerves of our bodies this function consists in sensation. The sensitive nerves are the media for the perception of all internal and external impressions. In the brain we become conscious of these impressions.

Hunger and thirst are the sensations which announce to the brain, through the medium of the nerves, the impoverishment of the blood. In popular language, every substance is called a nutriment which is able to quench hunger and thirst. The scientific definition of nutriment results from the cause of these sensations. Whatever substance possesses the power of restoring to the blood the essential constituents which it has lost, and begins the circulation from the blood through the tissues, may be considered a nutriment in the widest sense.

All the aliments which restore to the blood the compounds of chlorine, the salts, the fat, and the albumen, satisfy the sensation of hunger; that of thirst is quenched by the restoration to the blood of the deficient water.

§ 38. **Alimentary Principles.**—All nutriment is composed of certain *alimentary principles*. Under the latter term we comprehend all those compounds which are either identical with the essential constituents of the blood, or sufficiently similar to be transformed into them by digestion. Essential constituents of the blood are all those which do not originate from the regressive transformation of the tissues.

To this general definition we have to add, as a special one, the difference between alimentary principles and aliment. By ordinary dissolving media, like water, alcohol, and ether, simple constituents can be separated from the aliments, but not from the alimentary principles. These simpler constituents of the aliments, which cannot be separated by common dissolving media into any further parts, are the alimentary principles themselves.

Though the alimentary principles are often denominated the elementary constituents of the aliments, they are by no means to be confounded with the elements in a chemical sense. The latter cannot be decomposed into other substances manifesting, abstracted from form and colour, any essential differences; the alimentary principles can be decomposed, but only by agencies which act more powerfully than simple dissolving media, like water, alcohol, and ether.

No alimentary principle is composed of fewer than two elements; the simplest alimentary principles, like water and common salt, are combinations of two elements, the former consisting of hydrogen and oxygen, the latter of sodium and chlorine.

A great many alimentary principles, as fat, sugar, and most of the vegetable acids, contain carbon, hydrogen, and oxygen; the inorganic salts consist of oxygen combined in the basis, and the acid with two different elements. All these alimentary principles are formed of three elements.

Four elements are found in the soaps which, in addition to the carbon, hydrogen, and oxygen of these fatty acids, contain a metal, forming with oxygen the basis alkali of the soap.

Finally, those organic alimentary principles, in which nitrogen and sulphur are associated with carbon, hydrogen, and oxygen, are composed of five elements; and some others, containing phosphorus, of six. To the former belongs gelatine, to the latter albumen.

§ 39. **Digestive Principles.**—Before discussing the process of digestion, I classified the alimentary principles into inorganic, organic without nitrogen, and organic with nitrogen.

To the inorganic alimentary principles belong the compounds of chlorine, as common salt, and the combinations of inorganic acids and bases, which chemists, abandoning the ordinary usage of language, designate by the name of salts.

The starchy matters and fatty substances, with by far the greater part of the acids of our elements, are all alimentary principles without nitrogen.

Of the organic alimentary principles, the albuminous substances, the colouring of the blood, and the gelatine, all contain nitrogen.

The aliments which are composed of various alimentary principles cannot be classified, in a similar way, on any chemical basis into different groups; for the same alimentary principles appear in the most different elements, and their distinction depends either upon the quantitative proportion of the corresponding constituents, or upon some freshly supervening substances; but there is so great a variety, both in the proportion in which the ordinary alimentary substances are combined in the aliments, and in the nature and qualities of the superadded substances, that the aliments classified with respect to their chemical properties could be united into very small groups only,—a circumstance which would render difficult the review of the whole.

I have not, therefore, departed from the classification which has hitherto been popularly employed, but shall treat in succession on solid and liquid food, and on condiments. None of these sections need any further definition.

I must, however, guard against one error, not seldom met with. In believing that solid food only satisfies the hunger, while liquids only quench the thirst, we forget that there is only one alimentary principle—namely, water—which affects that condition of the blood which brings on thirst. But water is contained in all aliments in such an abundance, that, on an average, it constitutes more than half of their weight. All beverages, on the other hand, contain also some other alimentary principles than water; for even in what we are accustomed to call pure water, there are always contained some of the compounds of chlorine and salts; while in milk we have all classes of simple alimentary substances together, it being composed of water, compounds of chlorine, salts, caseine, fat, and sugar.

The condiments are also, in the restricted sense in which I shall employ the word, principally composed of alimentary principles; only a few of them contain substances which, although exciting the gustatory nerves and stimulating the digestive organs to a greater activity, may not also be considered as restoring some of the losses of the body.

§ 40. As the alimentary principles are not found in nature in their simplest form, so also none of them is sufficient of itself to nourish the body. Not even a variety of these substances, if belonging only to one of the three groups before-mentioned, are able, if exclusively eaten, to maintain life; I may go further, and add that life cannot be sustained by two of these sections, if the third is lacking.

Not sugar alone, nor salts alone, nor albumen, if taken without any substances of the two other groups, is able to destroy the consequences which the change of matter effects, when the process of excretion goes on, without the accompanying one of nutrition.

Without phosphate of lime the bones cannot be formed, whatever quantity of albumen and fat we may consume; no muscular tissue could grow without albumen, however we might overload the stomach with sugar and salts; and, finally, without fat, no brain. But the bones, the brain, and the muscles are the most essential organs of the human body.

No element can be transformed into another: this is the whole solution of the secret. Phosphorus does not turn into oxygen, nor oxygen into carbon, nor carbon into nitrogen, nor nitrogen into sulphur: no power short of the miraculous is able to effect an exception from this rule. As something cannot be created from nothing, no creative power of the body is able to transform iron into hydrogen, or chlorine into calcium.

The organic alimentary principles, destitute of nitrogen, cannot be transmuted into those containing nitrogen, nor the nitrogenized organic substances into inorganic salts containing any other elements than nitrogen, carbon, hydrogen, oxygen, sulphur, and phosphorus.

It might be supposed, that albumen could be transformed into fat, because albumen, as well as fat, contains carbon, hydrogen, and oxygen; it could also be suggested that carbonic alkalies and water, as containing carbon, hydrogen, and oxygen, could form sugar: but experience has shown that the animal body cannot accomplish the former transformation in a sufficient quantity, nor the latter at all.

Complete substitutes, therefore, of the nutriments which maintain the life durably, can only be formed by a combination of all three groups of the alimentary principles.

§ 41. **Tests of Digestibility.**—The more easily these alimentary principles are dissolved in the digestive fluids, and transmuted into the constituents of the blood, the greater is their digestibility: for digestion consists not in the solution of bodies only, but also in their transformation into the essential constituents of the blood. Both conditions are of equal importance.

If two substances, therefore, are dissolved with equal ease, that will be the more digestible which has the greater similarity to some constituent of the blood. Stearine and margarine, for instance, are almost equally soluble in the digestive juices; but as margarine is present in the blood, and stearine is not, it follows that margarine surpasses stearine in digestibility.

But if the conformity of two alimentary principles with the constituents of the blood is equal, the more soluble is the more digestible. Soluble albumen and fibrine stand equally near to the blood, both being contained in it. As the soluble albumen, however, is more readily dissolved in the digestive juices than fibrine, the digestion of the latter is more difficult.

Hence it results, that the difficulty with which alimentary principles are dissolved is, in many cases, compensated by their conformity with the ingredients of the blood. Although gum, for example, is much more easily dissolved than fat, the latter, if not taken in too great a quantity, is digested by a healthy stomach, under certain circumstances, more readily than gum; for gum is not contained in the blood, while fat belongs to its essential constituents. Gum has first to be transformd into sugar, then into lactic acid, and finally into butyric acid and some other fatty substances; while fat, on the other hand, as containing oleine and margarine, is represented in the blood itself. On the formation of fat from starch, the latter must first be changed into gum, then into sugar; the sugar into lactic acid, and this again into butyric acid. It hence appears, that of all these substances lactic acid is the most digestible, even if all were equally soluble in water; sugar would be the next to it, then gum, and finally starch. Lactic acid and sugar are, besides, more soluble than gum, and gum than starch. The latter is, therefore, for two reasons, the least digestible of the above-mentioned alimentary principles. It follows, again, from the same law, that a substance which is both more easily dissolved in water than another, and more readily transformed into the constituents of the blood, greatly surpasses the latter in digestibility.

Of the aliments, those are the most digestible which contain the greatest number of alimentary principles easily soluble, and easily turning into the constituents of the blood.

§ 42. **Tests of Nutritiveness.**—The nutritiveness of any kind of solid or liquid food depends upon three circumstances: its digestibility, the quantity, and the proportions of the alimentary principles contained in it.

If an aliment contains many indigestible substances, which are voided again in an undissolved state with the excrements, it must lose as much of its nutritiveness; for only that which passes as an essential constituent into the blood, is to be considered as an alimentary principle. The more digestible an aliment is therefore, other things being equal, the more nourishing.

In testing the value of a nutriment with respect to the alimentary principles contained in it, no regard is paid to the amount of water contained. Water is, in general, so easily to be procured, that we have not to take it into consideration, when judging of the value of solid or liquid food, with respect to its nutritious properties. In a dry arid desert, however, water would become the most important nutriment; and an aliment containing much water would be the most nutritious food. Where no deficiency in water exists, that aliment is the most nutritious which contains the greatest proportion of alimentary principles, and conveys, therefore, to the blood the greatest quantity of its essential constituents.

Besides the digestibility and the abundance of solid constituents, the combination of an aliment is also of the greatest importance. As the blood contains a greater proportion of albumen than it does of salts, and more salts than fat, the proportion of these alimentary principles will determine whether any particular food be nutritious or otherwise. Just as alimentary principles of equal solubility are the more digestible, the more completely they correspond with the several constituents of the blood; so an aliment is generally more nutritious, if the combination of its alimentary principles corresponds more exactly with the composition of the blood. Thus, nutritious aliment is characterised by containing, of nitrogenized substances, more organic than inorganic, and of substances not nitrogenized, more inorganic than organic matter. Lean meat is the food which most completely answers these conditions.

Substances from each of the other groups, however, as we have mentioned above, are equally indispensable, though requisite in different quantities. Compounds of chlorine, salt, fat, and constituents of fat, are as absolutely necessary as albumen or gelatine. It always betokens a narrowness of view, therefore, to speak of any aliment as innutritious. It is true, potatoes are less nutritious than meat, because the latter is very similar to the blood, while potatoes contain very little albumen and a large proportion of starch; but in the unqualified assertion that potatoes do not nourish at all, we forget that starch is transformed into fat by the digestive process, and that this represents an essential constituent of the blood. Potatoes combined with a certain proportion of white of egg become as nourishing as milk or meat.

To distinguish, in one word, between digestibility and nutritiveness, we may say that the former expresses the rapidity with which the alimentary principles of an aliment are transformed into constituents of the blood; the latter, the quantity of alimentary principles conveyed to the blood by solid or liquid food. Hence it follows, that we can speak of digestibility with respect to the alimentary principles as well as the compounded aliments, but of nutritiveness only with respect to the latter.

ON SOLID FOOD.

§ 43. **Meat and Eggs.**—In regarding the different kinds of food, from the whale-oil of the Greenlanders, and the bear's-grease which forms an article of diet in a Mogul tribe, up to the refined cookery of the wealthy in the more civilised countries of the globe, where, for instance, oysters and trepang (a small tubular animal belonging to the class of the Radiata) are favourite dainties, we soon find out that there exists no class of animals which does not furnish some contribution to the food of man. By all civilised nations, however, the flesh of herbivorous animals is preferred.

In this respect we may assert that the plants first prepare the food of man. It is an art in which they excel—that of preparing excellent meals from very simple materials.

It is true that those plants which prepare the most nutritious food, take also up some compounded organic aliments; but it is also undeniable that plants can live exclusively on carbonic acid, ammonia, water, and some inorganic substances, and in every case derive from these simple alimentary principles the chief bulk of their body. The carbonic acid, the ammonia (a very simple combination of nitrogen with hydrogen), and the water, are all three constituents of the air. "While the animal swallows bodies already formed," says Forster, who, before all others, deserves to be called the naturalist of the people, "these fine tubular and cellular formations eagerly take up the simplest elements from the air. Woven by sunshine and ethereal fire, such as formerly poets only dared to dream of, the soft green of the woods and fields smiles upon our sight; and behold! in the infinitely delicate network of the blooms and ripening fruits, glows the sevenfold beam, and adorns the vegetable world with the manifold brilliancy of its hues!"

Animals living on plants not unnaturally convey the impression of a greater purity upon our fastidious senses, which are offended by the rancid smell of the carnivorous Mammalia, and by the oily flavour of the birds of prey. Hence our predilection for the herbivorous animals; and among these the Ruminants and the many-hoofed occupy the first place. Throughout the whole of Central Europe, no meat is consumed in greater abundance than beef and pork.

§ 44. **Constituents of Beef.**—The flesh of oxen, or beef, illustrates the composition of all other kinds of meat. We may take the composition of beef as the standard, with which the varieties of the other most common animal aliments may be compared.

In beef, as in all aliments which, when taken to the exclusion of all other food, are able to maintain human life, the three groups of simple alimentary principles are represented. A combination of albuminous and fatty matters, of compounds of chlorine and of salts, abundantly diluted with water, is all that is necessary to sustain life.

The albuminous substances of beef are the fibrine of the muscles and albumen proper, The former constitutes the finest fibres of flesh; the latter is the essential body of the nutritious juice which occupies the space between the solid parts. The flesh owes its red colour to the blood which it contains in very numerous vessels; and this blood comprises albumen, globuline, fibrine, and traces of caseine, and in addition to these albuminous substances, some colouring matter containing iron.

The albuminous substances which animal food thus contains, are not the only supply it affords to compensate for the albuminous matters of the blood lost with the excretions; for the finest muscular fibres are enclosed in the cellular or binding tissue which unites them into bundles. This tissue, when boiled, yields gelatine, which is soluble in water. In the body, gelatine is again transformed into albumen. Convalescents very often regain their strength by the almost exclusive use of jelly from bones; and gelatine is the only nitrogenized body contained in any large amount in this jelly. As the blood of man, however, does not contain gelatine as a necessary condition of its regular combination, but albuminous matter, we must infer that the gelatine is transformed into albuminous compounds.

That the cellular tissue in the muscles is intermingled with elastic fibres, does not in any way affect the nutritious properties of animal food; for these elastic fibres are not dissolved in the digestive fluids. They constitute a part of those alimentary remnants which, united with certain excretory substances of the blood, compose the excrements.

Like gelatine, the horny cells lining the walls of the muscular blood-vessels are entitled to the name of constituents of albumen. They are, however, of small importance; for their quantity is so insignificant, that even if soluble in the alkaline secretions of some digestive glands, they are decidedly less digestive than the fibres yielding gelatine.

Kreatine, flesh-basis, and flesh-acid are regular nitrogenized constituents of beef. Are they to be considered as alimentary principles? There is scarcely any doubt that they pass into the blood, and from the blood into the muscles. But is mercury a nutriment because it passes through the blood into the basis, and is found there in the form of small glands? Against this opinion the judgment of even the unprofessional reader protests. And the kreatine, the flesh-basis and the flesh-acids, I cannot consider to be, strictly speaking, alimentary principles, as they belong to the regressive transformation, which process, by the action of oxygen, conveys all organic matters of our tissues to the excretory glands. The organic compounds without nitrogen contained in beef are much less various than the nitrogenized. The former consist of several fats, sugar, and lactic acid. I have often mentioned that the fat of the Ruminants owes its hardness to the stearine. This is associated with margarine and oleine; whilst the peculiar fat containing phosphorus, as well as the gall-fat of the nerves and the blood, scarcely deserve any consideration, on account of their small quantity.

Chloride of potassium and phosphate of potash are the peculiar inorganic substances of the flesh. They alone would be sufficient to distinguish the flesh from the blood. While the blood contains seventeen times more soda than potash, there is in the flesh of the ox about three times more potash than soda. Phosphates of soda, lime, magnesia, and oxide of iron are contained in beef, in somewhat considerable quantities; but there are only few traces of sulphates of the alkalies attributable to the blood of the muscles. The amount of water contained is so considerable that, on an average, it amounts to more than three quarters of the whole mass.

§ 48. **Effects of Cooking.**—The foregoing description refers to the raw flesh. What becomes of this when boiled or roasted? If we put a piece of meat into boiling water, and leave it long enough exposed to the boiling temperature, the soluble albuminous substances coagulate; the fibrine is transformed into two new compounds, each of which is richer in oxygen than the fibrine itself, and only one of which resembles fibrine in its difficulty of solution. The other, which may also be obtained from albumen, is easily dissolved in water.

The colouring matter of the blood turns brown from being decomposed at the boiling-point. By this process it also loses its solubility in water.

The cellular tissues dissolve, as by boiling they are transmuted into gelatine.

The fatty substances melt. Those of the inorganic compounds which are more easily soluble, are dissolved in the water. The same takes place with the sugar, the lactic acid, to which the flesh-juice owes its acidity, the kreatine, flesh-basis and flesh-acid.

The albumen being coagulated by the boiling-water in the external parts of the meat, forms around the internal part a cover or outside, penetrable only with difficulty. A large proportion of the soluble alimentary principles is consequently retained, which the water would otherwise have abstracted from the meat. The heat, however, penetrates to the interior; each flesh-bundle gets surrounded, as it were, by a sheath of coagulated albumen. This protects the gelatine and the salts, the lactic acid and the kreatine, but, most of all, the real flesh-fibre, which, by the direct action of the boiling-water, would gradually become harder and more tenacious. Accordingly, the flesh yields only very little of its constituents to the water, and preserves with the alimentary principles, not only its nutritiveness, but also its flavour.

If, therefore, the cook wishes to prepare a juicy, savoury, and rich food, she puts the meat into the water raw when the latter is in a state of ebullition; but if a strong broth is to be prepared, she puts the meat into cold water, and heats it gradually. The soluble alimentary principles are, by this process, abstracted from the meat and dissolved by the water before the albumen can coagulate. It is true, that when the solution boils, a quantity of small albuminous scales are formed, which are skimmed off with the colouring matter of the blood, which has now turned brown, and other adhering substances. But when the water boils, another part of the albumen is transformed into a combination containing more oxygen, and soluble in water. The same takes place with the fibrine of the muscles which comes into direct contact with the boiling water. Thus, a solution is formed consisting of transformed albuminous substances, kreatine, flesh-basis and flesh-acid, gelatine and lactic acid, besides some salts; while small scales of albumen and melted fats—the well-known fat-bubbles—float on the liquid in an undissolved state. The broth thus prepared is savoury, but the meat all the poorer and tougher, in proportion as the water has been more slowly heated, and afterwards, when boiling, its action longer continued.

This explains why in Germany, in the households of the middle classes, where meat is put on the fire with cold water, boiled meat is seldom or never taken without broth; for the boiled meat together with its broth contain the constituents of the raw meat. In other countries, the Netherlands for instance, boiled meat without broth is very common food. The Dutch cooks, therefore, put the meat which has not to furnish any soup, on the fire with boiling water.

By roasting, as in the former case, a kind of sheath is formed around the meat. The albumen coagulates on the external surface, which becomes of a deep brown by the decomposition of the colouring matter; and afterwards by the formation of several empyreumatic-smelling substances. This surface retains the greater proportion of the soluble substances in the meat, from which a thick substantial juice oozes out in a proportionately scanty quantity; a part of the fatty substance is decomposed, stearic acid, for instance, being transmuted into margaric acid; and finally, an important substance is newly formed—namely, acetic acid, which originates in the action of dry heat used in roasting, facilitates the solution of the albuminous matters.

Vinegar has the effect of rendering the meat more digestible, as also does common salt, by dissolving the albuminous substances, as has been mentioned in discussing the process of digestion. This is the explanation of an expression common in Germany, that vinegar makes the meat short, short meat being easy of digestion.

Large pieces of meat, which after boiling or roasting contain liquid blood in the interior, are, in Germany, considered not to be sufficiently done; whereas in England this is in many cases required as a proof of good cooking. What is the cause of the blood being thus retained? It is because the colouring matter of the blood is not decomposed, excepting where the temperature has been increased to more than 132° Fah. The internal parts which retain the crimson hue, have not attained this temperature.

§ 46. **Difference of Taste.**—Although the difference of taste in different kinds of meat would indicate material distinctions in their composition; yet the ascertained differences are very trifling in the case of the flesh of the sheep and roe; these belong, like the ox, to the class of Ruminants, and correspond most exactly with beef in the alimentary principles which they contain. The fat of sheep, however, is generally harder—that is to say, richer in stearine; and the fat of the roe is more acid than that of beef.

Pork is richer in fat, but poorer in albuminous substances than beef, although even here the difference is not considerable.

All wild Mammalia are remarkable beyond our domesticated animals for the quantity of kreatine which they contain; the latter, however, surpass the former in their proportion of fat. The reason of this is obvious. Whilst, in the ox fattening for food, its even and quiet existence promotes the formation of fat, and moderates the tissue change, the roe, leading in the woods a free and active life, takes in a greater quantity of oxygen, which transforms the nitrogenized basis of the tissues into kreatine. It is the same with birds; their rapid flight, and their bones filled with air, augment their reception of oxygen. The higher temperature of the bird proves that it consumes oxygen faster than the reptiles crawling on the earth; even faster than the Mammalia, the only class of animals with which it shares the appellation of warm-blooded. Hence, the more rapid decomposition of its albuminous matter, of which the proportion of soluble albumen is, besides, greater than in the other Mammalia; hence, also, the abundance of kreatine in the muscles of birds.

While between the Mammalia and birds no great difference has been observed in the amount of water they contain, the three quarters in weight of water contained in the flesh of warm-blooded animals is increased to four-fifths and more in the flesh of the fishes. Little blood, and therefore mostly a white colour: much less muscular fibrine: a larger quantity of tissue yielding gelatine: and, above all, a fat containing phosphorus, which is not limited to the contents of the blood-vessels, are regular peculiarities in the flesh of fishes. And this phosphorous fat does not constitute the only difference in their properties; for the soluble albumen of the fish, which nearly corresponds in quantity with that of the flesh of birds, coagulates much more rapidly in a somewhat higher temperature than the soluble albumen of the warm-blooded animals. The soluble albumen differs also from the latter by not containing any phosphorus.

§ 47. **Comparative Qualities of Flesh.**—We have to take into consideration not alone the species of the animals whose muscles furnish our meat, but also numerous other circumstances affecting the flesh, before it appears on the table.

Thus the flesh of young animals is poorer in fibrine than that of the mature, but richer in soluble albumen, gelatinous fibres, and water: it is therefore more tender. This preponderance of gelatine explains why the broth of veal and lamb sooner coagulates than that of beef and mutton; for it is the gelatine diffused through the broth which coagulates the whole, when cool, into a jelly.

Is the difference in the taste of the flesh of different animals, so familiar to us in ordinary life, traceable to certain differences in the composition of their food? The taste of fieldfares, for instance, after eating juniper-berries, and that of some ducks and other aquatic birds which feed on snails, crabs, and fish, and whose flesh resembles train-oil, evidently settles this question in the affirmative. In Tahiti the swine were fed on fruits only; and while their fat had nothing of the rich taste of European pork, Forster compared their flesh with veal. Science, however, answers the question with special regard to the fats; by its exact comparisons, it correctly explains the every-day experience of domestic life. There can now be no longer any doubt that the substitutes with which we feed our oxen, swine, and fowls, and stuff our geese—namely, turnips, potatoes, saw-dust, maize, rice, with several other seeds—are remarkable for abundantly containing the constituents of fat; for in these kinds of food the substances contained in greatest quantities are starch and sugar, with other similar matters, which the animal body transforms into lactic and butyric acids, and some other fats. Game, again, owes its savoury taste in great part to its large proportion of kreatine. Fattening causes the quantity of kreatine to decrease. Partridges lose their taste if cooped-up and fed like domestic fowls, as is sometimes done in severe winters to protect them from cold. Tame ducks, if left at liberty, become *lean*, but acquire the agreeable flavour of game.

Although it does not require a sentimental mind to regard the cramming of geese with a degree of aversion, yet man has not disdained much more cruel encroachments on animal life with the intention of procuring a new titillation to the palate. Not only has he made capons and poulards of cocks and hens by mutilation, but he has mutilated several Mammalia, as well as carps, in the same manner. Chemical research has not yet discovered why the flesh should become by this process more tender and savoury; but the fact is undoubted. Cows grow fat more rapidly after the loss of their ovaries. The practice of baiting carried on in former times, but at present only existing in the form of hunting, liquefies the fibrine, which is the least readily soluble alimentary principle of flesh, and renders the meat more tender.

§ 48. The intestines of some animals, the entrails in which sausages are made, the brain, the liver, the kindey, the spleen, and the sweet-bread, are very similar to flesh in the properties of their constituents; the differences being chiefly in their quantitative proportions. Liver, spleen, sweet-bread, brain, and kidneys, contain soluble albumen in remarkable abundance. In addition to this quantity of albumen, the sweet-bread contains much gelatinous tissue, and an extremely small proportion of fat; while in the brain and liver, a considerable quantity of phosphorous fat is intermingled with the ordinary alimentary principles.

In the bones, the nitrogenized alimentary principles are almost exclusively represented by the gelatinous tissues. Though there exists no doubt that gelatine is capable of being transformed into albumen, yet this transmutation takes place so slowly that the bones alone cannot yield a proper nutriment. Since gelatine, as such, is not present in the blood, it has therefore to be transformed into albumen in order to become one of its constituents; it is much more difficult of digestion than albumen, in spite of its facile solubility in the gastric juice. The bones are not deficient in fat and the more important salts; but as these pass only in part into the cakes made of the gelatine of bones for the preparation of broth, the use of these cakes as a principal supply of food is to be reprobated. In England, which excels all other countries in the preference of its people for a substantial nutriment, these cakes are prepared from the broth of meat inspissated by boiling to a jelly. Sometimes, indeed, bones and other parings may be used in addition; but fresh beef furnishes the essential constituent of the inspissated juice, which is poured into small cake-moulds. These cakes, when dissolved, closely correspond with real broth; and they therefore justly claim for themselves the name of portable soups. What in France is sold under the name of bouillon-cakes is nothing but gelatine; a production difficult of digestion, only slightly nutritious, and therefore objectionable. No economy is so nearly related to extravagance, as that of preparing soups from such cakes in order to effect a saving in meat; for this broth does not repair the expenditure of the body; and while impoverishing the purse, fails to enrich the blood.

§ 49. **Eggs of Birds as Food.**—No other aliment unites so completely the advantages of meat, as the eggs of our domestic birds. The yolk and white consist chiefly of albuminous matters,—the yolk of caseine and albumen, the white of soluble albumen, containing more sulphur than the homonymous compound of the blood,—and of an albuminous body containing a large quantity of sulphur, scantily soluble, and forming cellules in the shape of small membranes, which include the soluble albumen.

I have before explained why eggs coagulate when boiled. The heat of the boiling-water being communicated through the shell to the thick albumen solution, the albumen becomes hard.

The white of egg contains more water than the yolk; somewhat more than one-half of the latter, but only four-fifths of the former, consisting of water. The yolk is also in a nearly similar proportion richer than the white in fat and in albuminous substances. The yellow oil of the yolk contains a large quantity of oleine, with a little margarine, less phosphorous fat, and still less gall-fat.

What further does the egg require to represent a complete nutriment? Nothing but the salts and chlorine compounds of the blood; and all these are found in the inorganic constituents both of the white and yolk.

§ 50. **Animal Food Considered.**—"Flesh makes flesh." Thus says a popular proverb. I readily agree with this view, and that so much the more when I regard diet in its direct relation to our body, since the view is much more correct than if it had been said—"Flesh makes blood." It is not only the potash predominating in the flesh which distinguishes it from the blood, the latter containing soda in a greater proportion; for while in the blood more albumen than fibrine is to be found, the fibrine predominates over the albumen in the muscles.

Flesh, therefore, is much more capable of repairing the waste of our muscles than that of the blood.

Is this discordant with the fact, that all nutriments find their way to the tissues only through the blood? The chyle, originating from meat, is, like all the rest, mingled with the blood, to which it is conveyed through the thoracic duct. But as our flesh in great part consists, not by chance, but according to a necessary law of attraction, of chloride of potassium, phosphate of potash, and fibrine, an abundance of these constituents in the blood must be to the benefit of our muscles.

Under a predominant, and still more under an exclusive animal diet, the fibrine does, in fact, pass in greater quantity into the blood. The natural result of this is great vigour of muscle, as may be illustrated by the strong muscular structure and fiery movements of the Indian tribes in North and South America, who snatch a livelihood from the chase. Has not breeding cattle the same influence upon the Calmucs and Tartars, the pastoral tribes of the Alps, and the mountaineers of the Scotch Highlands? Who does not know the superiority of an English labourer, who is strengthened by his roast beef, over an Italian lazarone, whose predominant vegetable diet explains in great measure his inclination to idleness? And, finally, the slighter strength of the Laplanders and Samoyedes, of the Greenlanders and Kamtschadales, whose food consists almost wholly of fish, in which scarcely more than three-fourths of the fibrine found in the birds and animals is to be traced, is an additional proof of the truth of the sentence —"Flesh makes flesh."

The richer the meats are in soluble albumen, the poorer are they in fibrine and fat, the more easily digestible will they be, if other constituents do not neutralize this property. Thus the flesh of pigeons and fowls is more digestible than veal; veal more digestible than the muscles of oxen, sheep, and deer. Horse-flesh is, doubtless, very similar to the latter; and the Mongols and Patagonians, and even some Christian nations of Europe in times of famine, have proved its advantages as a nutriment; while recent investigations of the French physicians have scientifically established them. Unjustly, therefore, was the eating of horse-flesh declared by the holy Boniface to be a heathen indulgence of appetite, interdicted by Pope Gregory III. and other authorities. The quantity of fat places the muscles of swine and geese among the most heavily digestible meats; while, on the contrary, most of the different kinds of game owe their superiority to the small proportion of fat they possess, which distinguishes them from the meat of our high-fed domestic animals.

The flesh of fishes, according to their proportionately small quantity of fibrine and their abundance in soluble albumen, might be supposed easily digestible; but the quantity of phosphorous fat renders them difficult of solution in the digestive juices;—a remark which is applicable not only to fishes, but to the brain and liver of all vertebrate animals. Of the intestines, there is no aliment more easily digestible than the sweetbread of calves, which is remarkable for its slight quantity of fat and fibrine, as well as for its abundance of soluble albumen.

On account of the formation of acetic acid in the external parts, and of the less complete coagulation of the interior, roast meat, which does not contain too much fat, is easier of digestion than boiled.

Soft-boiled eggs are, on the whole, dissolved in the stomach with greater facility than hard ones; but as dissolved albumen is coagulated by the acidity of the gastric juice, and is afterwards dissolved again, the process of boiling the eggs hard, if not carried to excess, does not materially interfere with their digestibility.

As all kinds of flesh contain a sufficient proportion of fat and salts to restore to the human body the inorganic constituents of the excretions and the transformed fats, that kind of flesh, however, which contains the albuminous matters in the greatest abundance is to be considered the most nutritious. Venison and beef are therefore more nutritious than veal, and veal more nutritious than fish. Pigeons and fowls, however, surpass beef in nutritiveness, being not inferior in their proportion of albuminous matters, but superior in digestibility. Pork, also, is less nutritious than beef, from the twofold reason of its possessing fewer albuminous compounds, and of being, on account of its preponderant quantity of fat, less digestible.

When fibrine is abundant in the blood, the heart, being a tissue of muscular fibres, is more fully nourished; the activity of the circulation is consequently increased. The excitation of this activity, observed after a copious meal of venison, is due not only to the abundance of albuminous matters contained in the venison, but also probably to its proportionately large quantity of kreatine.

The formation of blood and the nutrition are increased by animal diet, as all these facts prove. Shall we therefore be surprised to find that, after a hearty meal of meat and eggs, the secretions and excretions containing albuminous matters, or compounds derived from them, likewise increase in quantity, and especially in their proportion of nitrogenized matters? That the semen is formed in greater abundance, the milk flows more copiously, and the quantity of urea and uric acid in twenty-four hours is considerably increased? Is it to be wondered at that the blood circulates more rapidly, that the muscles contract with greater vigour, and that the sexual impulse is more excited? Thus it is true that an abundant formation of blood gives the first impulse to an active metamorphosis of tissue; thus it is true that all increased activity has to be referred to a corresponding supply of new material.

§ 51. **Bread and Cakes.**—All kinds of corn, including rice, maize, oats, barley, rye, and wheat, contain in their seeds a large quantity of undissolved vegetable albumen, combined with a little vegetable gelatine. The latter compound, belonging, like the former, to the albuminous matters, is a glutinous substance, which communicates its property to the whole combination; from this circumstance it is called gluten. In addition to the gluten, formerly erroneously supposed to be a simple body, most kinds of corn contain a small quantity of soluble vegetable albumen.

The constituents of fat are also abundantly represented in all kinds of flour, for all kinds of corn contain a quantity of starch so considerable, as by far to surpass their amount of albuminous substances. Besides the starch, a proportion of gum is always present. Formerly, also, sugar was supposed to exist in these seeds; recent investigations, however, have shown this supposition to be incorrect, as far, at least, as regards wheaten flour in a fresh condition.

A small proportion of ready-formed fat accompanies the constituents of fat; and, finally, all the inorganic constituents of the human body are present in the seeds of the cerealia—namely, soda and potash, magnesia and lime, iron and chlorine, fluorine, phosphoric and sulphuric acids. The phosphates of the alkalies and earths predominate amongst the salts, and magnesia amongst the earths.

§ 52. **Composition of the Cerealia.**—The difference in composition which exists amongst the seeds of the cerealia is much greater than one would expect from the natural affinity of their parent plants.

Gluten and starch are the constituents of grain, in the proportion of which the greatest differences are found, the quantity of the one generally varying inversely as that of the other. Thus, wheat contains the greatest quantity of gluten and the smallest of starch; rye a medium proportion of both; while in rice and barley, in oats and maize, the largest proportion of starch and the smallest of gluten are to be found.

Potash considerably predominates over soda in the seeds of the cerealia: this has been established by the most recent completed investigations on wheat and barley, oats and rice.

Maize is remarkable for its considerable proportion of fattening matter. In the external covering of all kinds of grain, there are contained much more gluten and fat than in the interior. Peeled rice and pearled barley have, therefore, lost a great deal of their nutritiveness; and bread containing the bran is much more nourishing than that prepared from sifted flour; but, unfortunately, the former is rendered, by the hard cellular tissue which it contains, much more difficult of digestion than the latter, and excites an injurious irritation, causing diarrhœa in weak digestive organs. Sifted flour is, therefore, for general use, preferable to the unsifted.

If we consider that the breeding of cattle and agriculture are among the most ancient pursuits of mankind, we must not be astonished that, in the methods of increasing the produce of both, experience had anticipated science by some thousands of years. In many cases, therefore, nothing was left to the latter, but correctly to interpret the results of the former, and explain its principles. Often, too, the scientific explanation of a customary practice has proved the safeguard against those errors, which would have been sure to arise in reasoning from solitary instances experimentally established, without the sure ground of a general principle. If the agriculturist were but ready to acknowledge the services of the chemist, and the latter willing to co-operate with the former, then the power of mind and that of the purse, which have, in fact, but one common object in view, would not divide their forces; but to the obstinate pride of the theorist, who seeks to overthrow all that agricultural experience has established, there is only too often opposed the equally obstinate narrow-mindedness of the agriculturist, who has no faith out of the circle of his experience, or beyond the limit of his fields; the one forgetting that old customs have been confirmed by new reasons, at least as often as they have been set aside.

This state of things is, however, happily disappearing; at least in this country, agriculturists are now aware of the value of the chemical appliances to agriculture, and are not found to be backward in developing its resources. They are now aware that what feeding accomplishes in the stable, manure effects in the field; and while with cattle an abundant formation of fat is principally sought, the chief endeavours of the agriculturist are directed to the production of gluten. The greater the amount of nitrogen incorporated into the soil by means of manure in the form of ammonia, the more considerable is the yield of gluten, which by means of the seeds of the cerealia renews the blood of man.

Besides manure, the temperature exercises a most important influence upon the quantity of gluten produced by the gramineous plants of the fields. In summer, and in warm climates, more gluten is formed than in the corn of winter and of the rough north.

§ 53. **Constituents of Bread.**—Although bread is made of different cereals in different countries,—as of rice by the Hindoos, and of maize in Tyrol and at the Gold-coast,—wheat and rye furnish the flour chiefly used in the preparation of bread in Europe.

Our ordinary bread is prepared with leaven, and is, therefore, called leavened or fermented bread. Leaven is nothing else than a part of the common dough preserved until the next baking, during which time it has become sour. By the process of fermentation in this preserved dough, lactic and acetic acids are formed. Yeast may be substituted for leaven with precisely the same effect. In both, an albuminous compound is the occasion of the sugar formed in the dough turning it into a vinous fermentation. By this process the sugar is decomposed into alcohol, which evaporates, and into carbonic acid, which, inclosed by the tough gluten, is retained in the bread.

Flour, the ferment water, and salt, form the dough. In this a part of the starch has already been transformed into sugar; and by the action of leaven or yeast, this sugar is transmuted into alcohol and carbonic acid. The carbonic acid, which is prevented from escaping by the tenacity of the gluten, produces the vesicles which give to the bread its ordinary lightness. By the process of baking, a portion of the starch in the external layer of the bread is transformed into gum and sugar. The soluble albumen coagulates the process; the alcohol evaporates.

By exposure to heat, this crust becomes brown; a compound of an agreeable bitter taste is thus formed, similar to that produced by the roasting of different other organic compounds. This peculiar bitter principle is called "roast-bitter," or "Assamar." Bread is so easily soluble in water, that it is liquefied even by the humidity of the air.

Good wheaten bread is white; the real brown bread, as, for example, the well-known Westphalia rye bread called "Pumpernickel," is from rye. As wheaten flour contains more gluten than rye flour, the same proportion is found in white and brown bread; and as it is gluten which causes the sugar to undergo fermentation and retain the carbonic acid, the reason is apparent why rye bread, which contains a smaller proportion of gluten, is less spongy than wheaten bread. Stale bread is scarcely drier than fresh. In five days fresh bread loses one-hundredth only of its amount of water, and becomes stale even if it has cooled in an atmosphere saturated with moisture. But stale bread may be retransformed into fresh if put again into the oven, whereby a considerable amount of water is necessarily lost. Both high and low temperatures cause a change in the smallest particles, which has yet more closely to be investigated by science. It is, however, a fact, that stale bread is hard and firm, but not dry.

§ 54. **Nutritive Qualities of Bread.**—Bread is not, on the whole, so nutritious as meat, so far as the albuminous substances are concerned; for even the richest bread contains only about two-thirds of the quantity of albuminous matters present in beef.

The digestibility, moreover, of bread and flesh is not to be considered equal; for gluten is more difficult of solution by our digestive juices than the fibres of the muscles, and corresponds less intimately with the albuminous substances of the blood; therefore it is more slowly transformed into its constituents.

The starch, so abundant in bread, has to be transformed into fat. The inferior solubility peculiar to the ready-formed fat of the flesh is thus compensated.

Of the fat which the excretions subtract from the blood, bread is a much more productive source than meat; for more than one-third of wheaten bread consists of starch, while one-tenth in weight of gum, and a small quantity of sugar, is also contained in it. This predominance of the constituents of fat explains why bread contains much more of solid substance than flesh. In the former, the proportion of water scarcely amounts to one-third of the whole.

This abundance of the constituents of fat does not at all correspond in proportion to the small quantity of fat to be found in the blood; and in comparing the nutritiveness of flesh with that of bread, we must, therefore, decide in favour of the former.

The nutritiveness of the different kinds of grain is dependent upon their comparative proportions of gluten; for in all of them the constituents of fat are present in abundance. Wheat, rye, oats, barley, rice, and maize, form a series, in which wheat takes the highest, maize the lowest place with respect to nutritiveness. Thus in rice and maize there is scarcely to be found one-seventh of the amount of gluten contained in wheat. The same proportion of nutritiveness consequently exists in the bread prepared of these different kinds of grain. Chemical knowledge thus justifies the old usage which prefers wheat and rye-bread to all other kinds of bread.

§ 55. **Indigestibility of Cakes.**—Like stewed hare, or any other composite preparation of meat, cakes belong more to a cookery-book than to a treatise on food. Eggs, fat, sugar, different condiments, almonds, dry or fresh fruit, are mixed with the dough of different kinds of flour; and all these constituents will be spoken of in their respective places. Why are cakes less conducive to health than bread? This question is so important to that large class of housewives who are proud of their pastries, that I will not pass it without a reply.

Sugar is the constituent considered by most people the most dangerous, while it is in reality the least so. If not added in too great a quantity to cakes and tarts, sugar is transformed into lactic acid, and assists the stomach in digesting. It is the fat, so abundantly mixed with many tarts in the form of butter, and as a constituent of the eggs and almonds, which renders many kinds of pastry so difficult of digestion. The more these fats are transformed by heat into the products of their respective decomposition, the more will this be the case. For this reason, macaroons, almond-tarts, or chocolate-cakes, containing the fat of cocoa, are more indigestible than other fruit-cakes and pastry which contain neither almonds nor cocoa.

The indigestibility of the latter, however, corresponds exactly to the quantity of butter and yolks of eggs used in their preparation; for in the yolk the fat of the eggs is principally to be found. Cakes, therefore, containing only a small proportion of butter and eggs, are the most innoxious.

The roast-bitter, produced by baking in the crust of bread, originates in all farinaceous food in the same way. It is the substance which principally takes up water from the air, or the interior of the cakes, and causes the crust to be moist.

But why are cakes preserved in a moister condition, when kept in tin boxes secluded from the air? Because in a closed place the water of the cake evaporates less, and the cake therefore is less desiccated. The sugar, with which the surface is usually sprinkled, and the roast-bitter principle, attract the water from the interior of the cake; and after a time the sugar is found melted, and the crust humid.

§ 56. **Peas, Beans, and Lentils.**—Peas, beans, and lentils are comprised under the name of leguminous seeds. If we wished to divide all aliments into two principal groups, the former containing those of a higher nutritive quality, we should in this class the leguminous seeds together with meat and bread.

For the legumin, which is a constituent of all leguminous seeds, is contained in peas, beans, and lentils in so abundant a quantity, that this albuminous substance not seldom surpasses both the proportion of glutine in bread, and that of fibrine in meat. Legumin is soluble in water. Acetic acid precipitates a sediment in the solution, which does not dissolve again if a larger quantity of this acid be added. By mere boiling, the legumin does not coagulate; but this effect is produced on the soluble vegetable albumen, which, as in cereal grains, is also found in the leguminous seeds in a small proportionate quantity.

A considerable proportion of starch, accompanied by a good quantity of gum, and in the sugar-peas, for instance, by sugar also, take the place of the constituents of fat, in the interior of the seeds of peas, beans, and lentils. The husk of these seeds, as well as the shell of those beans which are eaten whole, consists in great part of a substance which forms in all plants the young cellular walls, and is therefore called the cell principle, or cellulose. This belongs to the constituents of fat; it is identical in composition with starch, and like this is transformed into sugar by acids. But this process of transformation is so slow, that the cellulose, which does not dissolve in water, belongs to the alimentary substances which are very difficult of digestion; so much the more so, as even the alkali of our saliva, bile, pancreatic and intestinal juices is only able to dissolve a very small quantity of cellulose.

The ready-formed fat associated in the leguminous seeds with the constituents of fat, is present in so small a quantity that, without their abundant proportion of starch and gum, the peas, beans, and lentils, would not be able to restore the fat of the body, which, after being decomposed by combustion into carbonic acid and water, we constantly exhale.

All the compounds of chlorine and salts of the blood are to be found in the leguminous seeds; the most abundant salts of the blood, the phosphates of the alkalies and earths, existing there in the greatest abundance.

§ 57. **Alimentary Principles.**—Legumin owes its name to the circumstance of its representing the most important alimentary principle of the leguminous seeds; for it represents the albuminous substances in the peas, the beans, and the lentils, which contain only a small proportion of soluble albumen besides.

How is it that peas, beans, and lentils, become hard by boiling, as the legumin does not coagulate under the influence of boiling-water, and the proportion of the coagulating soluble albumen is so small? Because the chemist and the cook employ a water altogether different. The chemist operates only with water free from all dissolved substances. He first causes the rain or spring-water to evaporate by heat, and condenses again the vapour so formed in a low temperature; the water thus distilled containing none of those compounds of lime which are found in all the water used by the cook. But, in boiling, the lime unites with the legumin, and transforms it into a very hard substance; and as rain-water contains a smaller quantity of lime than spring-water, the peas remain softer in the former than in the latter.

By the process of boiling in rain-water, which contains but a small proportion of lime, a considerable part of the legumin is dissolved. It is better, therefore, both for the blood and the purse, to eat peas, beans, and lentils not in a dry form, but prepared as soup. Just as boiled meat should be partaken together with its broth, in order to get the most digestible and nutritive part of the meat, so in pea and lentil soups, the fluid part is better than the undissolved portion. A great part, therefore, of the nutritious substance is thrown away if we only eat the peas which have been boiled in water, and throw the liquor away.

§ 58. **Digestibility of Leguminous Seeds.**—In respect of digestibility, the leguminous seeds, if taken without husks or skins, hold an intermediate place between meat and bread; for the fibrine and albumen have an advantage over legumin in their greater conformity with the constituents of the blood, while legumin surpasses the gluten of the bread in solubility.

But if water which contains much lime, as is often the case, renders the legumin hard, and if the seeds are rendered more difficult of solution by the presence of their husks, peas, beans, and lentils become dishes difficult of digestion, and occasion flatulence. This shows the advantage of dissolving the soups of the leguminous seeds in rain-water, and straining them through a hair-sieve after the bursting of the husks by boiling. Peas, beans, and lentils, with their husks, require very vigorous organs to digest them.

But the leguminous seeds, though inferior to meat in digestibility, are superior in the abundance of solid constituents which they contain; for the proportion of water in peas, beans, and lentils is scarcely one-sixth of their weight; and while the quantity of albuminous substances may surpass that contained in meat by one-half, the constituents of fat and the salts are also present in the leguminous seeds in a greater abundance.

Blood and flesh, milk and semen, are therefore abundantly formed by peas, beans, and lentils; and for this reason they are the comfort of poor people, to whom meat is so seldom and so sparingly allotted.

I have already mentioned the considerable proportion of phosphorus contained in legumin; but the brain cannot exist without the peculiar fat containing phosphorus, which owes its origin to the albumen and fibrine of the blood. Phosphorus cannot be formed from any other element. It necessarily follows, therefore, that meat, bread, and leguminous seeds are serviceable in supporting the nutrition to the brain; and that aliments like fish and eggs, which contain a ready-formed phosphuretted fat, will facilitate the conveyance of this peculiar constituent of the brain. The formation, and therefore the activity of the brain, also, is dependent on this fat containing phosphorus; and it has been said, as a mere pleasantry, that a sagacious man has much phosphorus in his brain. The chemical combination of an organ is as much impaired by containing too much of a constituent, as by possessing too little. There is no danger that the laws of regular attraction, upon which the nutrition of the tissues is dependent, should allow the excessive supply of a single constituent; but the function suffers if this constituent is present in too small a proportion. We cannot, therefore, presume an abundance of phosphorus in great thinkers; while yet it remains true, that no phosphorus, no thought.

§ 59. **Vegetables.**—Meat and vegetables are aliments so generally used together, as inevitably to suggest the presumption that one is complemented by the other; and on investigating the composition of the different kinds of vegetables, such as cabbage, cauliflower, salad, spinach, sorrel, of hop, purslain, and asparagus, nine-tenths of their weight will be found to consist of water, with scarcely half-a-hundredth part of soluble albumen. Although the proportion of the constituents of fat, especially of cellulose and gum, in addition to starch, wax, and the green nitrogenized matter of the plants, exceed the albumen in quantity, yet it is evident, from the considerable abundance of water, that the constituents of fat form only a very small proportionate part of the above-mentioned vegetables.

But the leaves and young shoots which are used as dishes of vegetables, contain besides several organic acids; asparagus, for instance, with all the cabbage tribe, possesses acid of apples, or malic acid; the sorrel, oxalic acid; rhubarb contains both malic and oxalic acids. Malic acid consists of carbon, hydrogen, and a large proportion of oxygen; while oxalic acid, like carbonic acid, is composed of carbon and oxygen only, but with a smaller proportion of oxygen than is contained in carbonic acid. Both these vegetable acids have the power of keeping the soluble albumen of meat in a dissolved state. In asparagus there is associated with the malic acid another body, the asparagine, neither acid nor alkaline, but remarkable for its amount of nitrogen. Finally, the sourkrout, the dainty of a German citizen and the relief of an English sailor, derives its name from a sourish taste occasioned by lactic acid, produced by the following process:—The cabbage, which is cut into slices and placed in a barrel, intermingled with a certain quantity of common salt, is pressed down, and in this state it undergoes fermentation; lactic acid, together with a small quantity of butyric acid, is thus produced.

The dissolving action of these acids—for they act also upon the fibrine of flesh—is assisted by their abundant proportion of compounds of chlorine and of salt. In cabbage and asparagus, lettuce and cabbage sprouts, potash considerably predominates; in spinach, soda and potash are nearly equal; while in rhubarb a considerable amount of lime is contained. Cabbage sprouts are remarkable for their amounts of lime and magnesia; and in the stalks and leaves of lettuce, in asparagus and cauliflower, traces of manganese, a metal very similar to iron, have been found.

§ 60. **Digestibility of Vegetables.**—Are we, then, to express surprise that those vegetables should be praised, and put in comparison with meat, as aliments which dilute the blood, when we know that their solid substance often forms scarcely one-tenth in weight of the whole; and, moreover, that it contains more salts than albumen, without any undissolved albuminous substance at all, but merely a small proportion of organic acid? Whilst by themselves conveying very little nutriment to the blood, as may be seen in the feeble muscles of the inhabitants of the tropics, who live exclusively on herbs, vegetables are of service, first in the digestive canal, by dissolving the albumineous substances of the meat, and afterwards in the blood itself, by keeping the albumen and fibrine in a liquefied state, but not as nutritious food.

The cellulose, which in several kinds of cabbage, especially in the stem, is present in a greater abundance, belongs to an alimentary principle difficult of digestion; and this explains the flatulence which cabbages not unusually occasion in weak digestive organs. Of all other kinds of cabbage, the white cabbage used for sourkrout is remarkable for its amount of lactic acid, which renders it a readily digestible aliment. This useful vegetable dish is sometimes charged with indigestibility—a charge which should be brought against the pork and hard-boiled mashed pease so often taken with it.

If it is, therefore, apparent that vegetables alone furnish a very insufficient compensation for the excreted substances, the fact that an exclusively vegetable diet affords but a defective nutrition to the tissue is at once explained. Not only do the muscles become powerless, but a smaller quantity of nutriment is conveyed to the brain. Hence results an irresolute will, and a cowardly relinquishment of independence, as illustrated in the timid and slavish Hindoos and other inhabitants of the tropics, who feed almost exclusively on vegetables.

Since, moreover, the alimentary principle of vegetables requires less oxygen than meat, bread, or the leguminous seeds for the production of the same quantity of carbonic acid and water, while, at the same time, the amount of oxygen we inhale remains undiminished, it becomes evident why we exhale more carbonic acid while living on vegetables, than when supported by a more invigorating diet of meat, bread, and leguminous seeds. Precisely for this reason do we become satiated in a short time by an exclusively vegetable diet; for the blood and the tissues are only scantily supplied with albumen. But these tissues, containing a scanty amount of albumen, furnish fewer nitrogenized products of decomposition; and the excretion of urea and uric acid is, during the twenty-four hours, considerably diminished. The amount of urine, however, is increased by the salts and acids of the vegetables; and everybody knows how quickly the constituents of the asparagus, conveyed to the blood and attracted therefrom by the kidneys, manifest themselves to the sense of smelling in the urine.

By substituting vegetables which are poor in albumen, for one part of the meat we take as a meal, the supply of albuminous bodies is diminished, and the digestion of what we have taken facilitated. Thus a combination is performed intermediate between meat and vegetables; the blood contains more water than the meat, more solid substance than the vegetables; and, by adding together the amount of albuminous substances in the meat and vegetables, and dividing the total into two equal parts, the average quantity of albumen in the composition may be found approximately corresponding with that in the blood. Thus the seeming chance becomes an approved law; and, instead of an arbitrary taste being left to dictate the choice of aliments, the necessity of attending to the law is apparent, clear light being thus thrown upon the connection between nutriment and blood; and the night, in which the realms of knowledge were peopled with nebulous spectres and conjectural dreams, tending to show that all things existed for a settled purpose, is turned to day and conviction by the discoveries of science.

§ 61. **Potatoes and Edible Roots.**—Although in ordinary life we class the potato and other edible roots in the same category as the vegetables, we must not forget that these roots and tubers considerably surpass the latter in the quantity of solid substances which they contain; on an average, the proportion of water they contain does not exceed that of meat.

Are, then, potatoes and edible roots to be compared with meat in their nutritive qualities? Here it appears how important it is to compare the connection between the several groups of alimentary principles represented by the solid substances, with the composition of the blood, if we would accurately estimate their nutritive quality. By such comparison it will be found that in potatoes, in turnips, in carrots, in beet-root, in parsnips, and in Jerusalem artichokes, in leeks and celery, in shallots, onions, and radishes, the constituents of fat surpass the albumen in precisely that proportion in which the latter ought to have exceeded the former, had these edible roots been intended of themselves to sustain the composition of the blood; thus the soluble albumen, which alone represents the albuminous substances in these roots, often constitutes less than one-hundredth, and sometimes only two-hundredth parts in weight, while the constituents of fat fluctuate between one-fourth and one-fifth.

In the several roots and tubers the constituents of fat are very different in kind. Cellulose and gum are indeed found in all of them; but while the potato is remarkable for its amount of starch, we find in carrots, beet-root, and Jerusalem artichokes, an abundance of sugar also.

The roots just mentioned as abundant in sugar, as well as in turnips, contain a new compound of carbon, hydrogen, and oxygen, which contains more oxygen in proportion to its hydrogen than the constituents of fat. This substance in the unripe fruit thickens the walls of the cells, consisting of cellular tissue, and is denominated vegetable jelly or pectose. By boiling, it is transformed into a gelatinous substance called pectic acid, which might, therefore, be called gelatine acid. But since this gelatine acid is not transmuted into sugar, either by our digestive juices or by any artificial means, the vegetable jelly and the gelatine acid cannot be classed with the constituents of fat.

Fat is contained in potatoes and carrots in very small quantity; while in artichokes, besides fat, a trace of wax has also been found. Parsnips contain, with a great amount of starch, a considerable proportion of a fatty oil.

The pungent taste of leeks and garlic, of radishes and horse-radish, of onions and parsley root, is produced by certain volatile oils; for these oils, if extracted from the roots, will be found to possess exactly the same peculiar pungent smell and acid taste as the roots themselves. The garlic oil, exceeding all other oils in pungency of taste and smell, is composed of carbon, hydrogen, and sulphur, and is imperfectly soluble in water.

Organic acids, which I mentioned as characteristic of vegetables, are also to be found in these roots: thus the malic acid in potatoes and carrots; the citric acid, composed of the same ingredients as the former; and tartaric acid, containing a greater proportion of oxygen than the former, is found in the Jerusalem artichoke. Citric acid has been observed in several roots, which are remarkable for the above-mentioned volatile oils.

Asparagine is found in potatoes, which also remind us of the composition of asparagus, by their containing malic acid.

While all the inorganic elements of our bodies, with the exception of fluorine, are found in the potato, it is characteristic of turnips that they contain no soda, and only very little iron. By way of compensation, they possess a large quantity of potash, which is also contained in the ashes of potatoes, in a greater proportion than all the other inorganic constituents put together.

§ 62. **Comparison of Roots and Vegetables.**—In comparing potatoes and other edible roots with esculent vegetables, we find the latter inferior in digestibility and nutritiveness to the former; for, in the roots, not only are the different constituents of fat—namely, starch, gum, and especially sugar—more readily soluble than the cellulose of the vegetables; but these constituents of fat and the albumen, however small the proportion of the latter may be, are also much more abundantly present in roots than in leaves and stalks.

But if we contrast the roots with the group of the more nutritious aliments, as meat, cereal grains, and leguminous seeds, we find even the least substantial aliment of this group more nutritious than any edible roots. Rice and maize are not only richer in albuminous substances than roots, but exceed them nearly fourfold in the amount of starch which they contain.

The edible roots, as well as vegetables and fruit, belong, therefore, to the less nutritious aliments, and may be united into a second group, the first being formed of meat, bread, and leguminous seeds.

In this second group, potatoes and carrots, it is true, are distinguished from the other members by their superior nutritiveness, as well as by their digestibility. But, notwithstanding this, what must we think of the value of a nutriment in which the albumen and the constituents of fat are contained in an exactly inverse proportion to that which exists in the blood? It may, indeed, overload the blood and the tissues with fat; but inasmuch as it provides the blood only scantily with albumen, it conveys no fibrine, and, therefore, no strength to the muscles; nor can it furnish any albumen or phosphuretted fat to the brain. Now what would be the consequence if we were to accustom ourselves to eat such a quantity of potatoes as would suffice for providing the blood with the requisite proportion of albumen by their means alone? It is very obvious if through this excessive supply the process of digestion did not come to an entire stand-still, a superabundance of fat would be formed beyond the power of the oxygen to consume, and this fat would successively absorb from the albuminous substances a part of this vital element. A barrier would thus be raised against the endless change of matter in the tissues, against nutrition and regressive transformation; and only a portion of the material, and that the less important one, would take a part in that course of decay and reparation, by which the will and the energy, the movements and the thoughts, are brought to act.

It is this which so immensely aggravates the weight of poverty. The ill-satisfied want may be tolerated for a time; the strength of the arm may by strenuous efforts, and with the hope of obtaining better food, for a time uphold the fainting courage; but can a lazy potato-fed-blood confer on the muscle the power necessary for this labour? or on the brain the necessary vivifying impulses of hope?

§ 63. **Taste.**—It is not only the peculiar taste which is produced by the volatile oils existing, as above stated, in the several roots; that taste is but the first link to a long series of impressions effected by these oils upon the body. The different kinds of leeks, onions, and radishes, accelerate the pulse; the oil is conveyed to the nerves with the blood, the irritability is increased, and the sexual impulse excited by them; the smell of the oils is communicated to the breath; and, apart from the flatulent risings caused by the radish and horse-radish, it may be perceived immediately from the exhaled air that onions, leeks, or garlic, have been eaten. Through the action of these oils the kidneys abstract water from the blood, for the diuretic effect of these roots is well known.

§ 64. **Fruit.**—Vying in scent and colour with the flowers of the fields, fragrant fruits decorate our orchards; and though the savoury mango does not tempt the tongue in our climate, and the fragrant pine-apple only belongs to the luxuries of the rich, still the appliances of horticultural skill have given an exquisite delicacy to our apples and pears, and transplanted the cherry and peach from Asia Minor; while active commerce provides us with the orange and the lemon.

The nutritive and refreshing qualities of so many noble fruits have not escaped the researches of chemists. The cause, however, of so many subtle varieties of taste and odour has not yet received a satisfactory chemical elucidation. It is true we know the volatile oil which causes the peel of lemons and oranges to throw out afar their peculiar fragrance; it is true we conjecture that some fine sorts of ether reside in raspberries and peaches; but much, even almost all, has still to be explored. At least if the causes of variety are to be as lucid to our mind as the variety itself is delightful to our palate, it remains to be investigated.

Cellulose, gum, and sugar—constituents of fat, therefore, both of difficult and of easy digestion—are to be found in all fruits, as in apples, in stone-fruit, in berries, in oranges, and in melons. These components are associated with but a small proportion of albumen; it is even smaller here than in vegetables, though here and there, as in apricots, it is greater. The proportion of water contained in fruits is intermediate between that contained in edible roots and in vegetables.

Fruit-marrow, or pectose, a substance we have already specified as found in several roots, is abundantly present in all unripe fruits. While the fruits are ripening, this is gradually transformed into the constituent of vegetable gelatine (pectine), which by boiling becomes gelatine acid.

Several peculiar colouring matters, together with wax, produce the brilliancy of colour in the peel of cherries and apples. Like a film, they cover the skin; a touch of the finger deprives the peach of that tender waxy bloom, which in fragrance surrounds the fruit with a virgin-like adornment.

Different acids, supported by several salts, cool and refresh our thirsty tongues; as, for instance, malic acid, present in almost every fruit, especially in apricots and peaches, in apples and pears, in gooseberries and currants; citric acid, present in lemons and raspberries, grapes and pine-apples; and tartaric acid in grapes and figs. The skin of grapes derives its stringent taste from the tannic acid, which in many other fruits, as in acorns, produces a taste entirely bitter.

Almonds and nuts, as well as the kernels of stone-fruit, contain an albuminous compound (emulsine), which I call *ferment of almonds*. In a temperature somewhat raised, this ferment of almonds causes another nitrogenized substance, contained in bitter-almonds and in kernels of peaches, and called the *almond-principle* (amygdaline), to undergo a fermentation, by which the volatile oil of bitter-almonds and hydrocyanic acid are formed.

As chestnuts are distinguished by their amount of starch, so almonds and nuts are characterized by their abundance of an oil consisting of oleine and margarine. It is only from compliance with custom that I place almonds, nuts, and chestnuts in the group of fruits, as their very slight proportionate amount of water decidedly approximates them to the group of the more nutritive aliments.

§ 65. **Degrees of Acidity.**—Ripe and sweet, sour and unripe, are, in popular language, words of the same signification. Wrongly, if we ascribe the degree of acidity to the proportionate abundance of acid; for in the ripe fruit, the proportion of acid is very often increased; but the sugar, which has augmented in a still greater proportion, moderates the sourness, which in the unripe fruit predominates over the sweet, though the quantity of acid is actually smaller.

In ripe fruit the acid is enveloped in the sugar, just as in stewed fruit it is by the jelly; for the vegetable jelly of the raw fruit deserves this name only when stewed. It is true by this process a new acid, the gelatinous or pectic acid, is formed. The latter, however, in the form of a mucous jelly, weakens the other acids. Stewed fruits and fruit-jelly prepared with sugar are therefore less injurious than raw fruit, so far as concerns the irritating power of the acids and salts, as the interior coating of the digestive tube is protected by the gelatinous acid.

Apples and berries, cherries and plums, apricots and peaches, melons and cucumbers, with all other similar fruits, dissolve the albuminous matters, and exercise a cooling influence upon the blood. While more nutritious than vegetables, and less so than potatoes, they have a great advantage over the latter in not over-loading the blood with fat. A thinner blood circulates with much vivacity through the vessels of the inhabitants of the South Seas; "these blessed countries," to use the words of Forster, "the cradle of the younger human race, where, not yet condemned to slavery, it enjoyed all the rights of free men, without being compelled to purchase at too high a price the happiness of existence in sweat and exhaustion."

ON LIQUID FOOD.

§ 66. **Water.**—If life consists in a metamorphosis of the tissue, fluids are an indispensable condition of life; for the combinations and decompositions in its substance, produced by the activities of our body, cannot take place without the agency of water. The simplest beverage is therefore at the same time the most accessary of all.

It is true, the same combination of hydrogen with oxygen, which constitutes the essential ingredient of all drinkable water, is contained in a small proportion even in the driest food; but neither meat nor bread, still less the leguminous seeds, are so abundant in water as to be capable of maintaining the proper composition of the blood. And who is not aware from his own experience, that the most nutritious aliments are precisely those which most stimulate our thirst?

But it is impossible in our climate, with our activity, with the vigour of our changing tissues, to live only on fruit and vegetables, meat and bread, and peas and beans. Our most important aliments must be intermingled with a fruit abounding in water, if the water, which is abstracted from the body through the skin and lungs, the intestines and kidneys, is to be restored by a process of uninterrupted attraction.

Our drinking-water is the liquid which contains the greatest proportion of nutriment; for is that not a nutriment which conveys to the blood the substance that renders possible the motion of all other combinations? Is not the water to be considered a restorative substance, inasmuch as the water, which constitutes three-fourths of the blood, is continually being withdrawn by all excretive organs without exception?

And yet drinking-water is nutritious not alone because it contains water. The warmth of the earth indefatigably raises water into the air. From brooks, rivers, and seas, from plants also and animals, there arise uninterruptedly through the action of heat, vapours which are condensed into clouds in the higher strata of the atmosphere. If that were true, which in a coward passion for repose has so often been imputed to nature, that its activity never deviates from the strictest method of quiet development; evaporating water, if falling down as rain, would provide us with water only. But the dashing of the sea, and the storms of the air surrounding the earth, the pressure of the atmosphere, and the power of fire, very often impel the vapour upwards with so furious a violence, that all substances dissolved in the water are carried with it. Hence, even the purest water falling down from the clouds is impregnated with salts. Common salt and chloride of potassium, lime and magnesia combined with sulphuric and carbonic acids, magnesium with chlorine, even iron and manganese, have been found in rain-water; and however slight the proportionate amount of these fire-proof constituents may be, the regularity of their indications establishes the law.

In a greater abundance, however, than with these solid bodies, rain-water is impregnated with air. Oxygen and nitrogen, and the most important nutriments of the plants, carbonic acid and ammonia, are taken up by the falling rain watering the thirsty earth, and fertilizing the fields; and even the lightning renders its assistance in enriching the verdant clothing of the ground. Its spark unites nitrogen and oxygen into nitric acid, and the thunder-shower supplies to the plant the nitrate of ammonia.

To ammonia especially, rain-water owes its softness; while lime renders the water, containing a greater proportion of salts, hard, as we have it in our wells and springs. The carbonic acid of the water dissolves the chalk of the earth, and the water itself dissolves the gypsum, or sulphate of lime, which forms the deposit when in the process of boiling a considerable quantity of water is evaporated.

The quality of spring-water is as various as the earth through which it oozes. Earths and alkalies, combined with chlorine or sulphuric acid, with carbonic or nitric acid, with iron and manganese, are contained in the water of wells and springs in the most varying proportions. One or the other of those substances is often absent. Phosphoric acid never forms a constituent of water, notwithstanding the predominance of the lime-salts in wells and fountains.

That which causes the water of swamps and lakes, of rivers and seas, to be almost always unfit for drinking, is the admixture of putrefying organic substances, besides the common salt of the sea, which impart a putrid taste to it. Now it is the bottom of the sea, which, like a retort, sends the water up into the air; from which, as if distilled into rain, it streams down again in a potable condition: now it is the earth, forming, as it were, a strainer, through which the water, though not entirely purified, bubbles out of the wells. Even the skin of man possesses some of the properties of a filter. Cast upon a rock where not a drop of fresh water refreshes the languishing tongue, the ship-wrecked man bathes in the sea in order to escape the most tormenting death from thirst; and from the sea-water itself, a refreshing moisture, with a smaller proportion of salt, penetrates the thirsty body.

§ 67. **Water Essential to Digestion.**—Since the last result of the whole process of digestion is a liquefaction of the alimentary principles, the formation of blood is impossible without water; but not only the formation, but the continual exercise also of the organs depends upon their receiving a due amount of water. Without it, no digestion or formation of blood, no nutrition or excretion can exist. Even this statement, however, by no means exhausts the importance of water; for it is essential, not only as the medium for the movement of all dissolved substances, not only as the humidity necessary for the organs, of which the most active, the brain and the muscles, contain the greatest proportion of water; but the hydrogen and oxygen which we take in water, enter into the composition of many alimentary principles by being transformed into the constituents of the blood. When starch or gum becomes sugar, the transmutation is effected by the absorption of water; for, with regard to their composition, a greater proportion only of water distinguishes sugar from starch; and separation of oxygen from sugar, causes the latter to be transformed into fat.

No alimentary principle is so easily removed from the body as water, if taken in excess; for as no decomposition is required in order to its being attracted by the lungs, the kidneys, the skin, and the sudoriferous glands, it is not even necessary for this process that a greater proportion of oxygen be taken in. Water, taken in abundance, increases, at a low temperature, the activity of the kidneys; at a higher, the perspiration. He, therefore, who takes more water than necessary for nutrition and excretion, produces, in winter time, a proportionately greater quantity of urine; in summer an excessive perspiration.

§ 68. **Milk.**—A nutriment like milk, which during the whole period of life is of itself capable of sustaining the formation of blood, is, as it were, a ready answer of nature to the question—What alimentary principles are required for the formation of a complete nutrition? When treating on digestion, I took milk as the prototype of a perfect nutriment. It is at once a solid and a liquid food, a source of albumen and of fatty substances, of sugar and the salts—in one word, it is the most perfect of nutriments.

While more abundant in water than our blood, more abundant than bread and meat, milk possesses in caseine, a representative of the albuminous substances, accompanied by the ready-formed fat of the butter, by a constituent of fat in the sugar of milk, and by the most important salts of the blood.

Contained in small cellules, which it dilates into glittering globules, the fat rises to the surface of the milk which stands undisturbed, forming the cream; while the lower, and far more abundant part, contains the chief quantity of the caseine, the milk of sugar, and the salts. More than one-third of these salts consist of phosphate of lime, associated with the phosphates of potash and magnesia, with some traces of oxide of iron, chloride of sodium, and a large proportion of chloride of potassium.

§ 69. **Qualities of Milk.**—Although the milk of goats and sheep may derive their peculiar smells from the uncombined state of one of the volatile fatty acids, which in the milk of the cow are united with glycerine into neutral fats, the more important difference between the milk of women and that of animals is exclusively dependent on the different proportion of caseine and sugar of milk, of butter and salts, to be found in these several sorts of milk. Thus, the quantity of caseine in human milk is only half as large as in that of the cow; and while, in the latter, butter and salts are likewise contained in greater proportion, human milk exceeds this in the amount of sugar of milk by more than one-half. However slight the sweetening property of sugar of milk may be if compared with cane-sugar, the babe does not fail to distinguish the milk of its mother from that of the cow by its sweeter taste. The peculiar butter-fat, or butyrine, of the chemist, which, at ordinary temperature, is more fluid than margarine or oleine, must be contained in the human milk in a greater abundance than in that of the cow, as the butter of the latter is of a firmer consistence.

Immediately after confinement, human milk contains a much greater proportion of solid substances, particularly of butter, than it does some days afterwards. After a striking diminution of these contents of the milk, which has already become remarkable the fourth day after confinement, the proportionate quantities of caseine and salts increase again. After weaning, the milk is again impoverished with equal rapidity.

§ 70. **Formation of its Acids.**—By the influence of the caseine of the milk, its sugar is transformed into lactic acid, especially at a higher temperature, or in thunderstorms. As oxygen promotes the formation of lactic acid, boiling protects the milk for some time from turning sour—the oxygen which is contained in the milk being expelled at the boiling point.

The formation of this acid takes place so much the more easily, inasmuch as lactic acid is identical with sugar of milk in its composition. The sour milk becomes thick from the caseine being coagulated by the lactic acid which has been formed; curdled milk is that in which caseine has been coagulated by the spontaneously transformed lactic acid.

If from the curdled milk, the caseine, to which a great part of the butter adhères, is taken off, the whey remains, which is a solution of lactic acid, salts, and sugar, with a much smaller proportion of caseine and butter than is contained in pure milk.

In butter-milk the proportionate quantity of butter especially is diminished; for it is the remaining part of the cream from which, by the process of churning, the fats have been taken off. It always contains, however, some traces of butter, almost all the sugar of milk, the salts, and the caseine, very little of which passes into the butter.

§ 71. **Digestibility of Milk.**—It is natural to suppose that the nutriment of the infant must be readily digestible and nutritious; and both suppositions are verified by experience: for while caseine belongs to the most soluble of albuminous bodies, the more soluble fats are represented in the butter. Next to cane-sugar, the sugar of milk is the most readily digestible of all constituents of fat, and its transformation into fat is facilitated by the butter and caseine associated with it. With the easy digestibility of the milk its nutritiveness is also proved; nor need we be astonished at the abundance of water in an aliment, which at the same time furnishes the infant with solid and liquid food. And if the weight of the caseine scarcely amounts to one-sixth of that of albuminous bodies in beef, we must not forget that we commonly take the latter diluted—as in the form of soups, or associated with vegetables or edible roots; combinations by which the proportionate amount of albumen is considerably diminished. But the quantity of sugar of milk in the human milk is twice as great as that of caseine, and the butter is intermediate between both.

The milk of cows is often assimilated with difficulty by weak digestive organs, from the large proportion of butter it contains; but skimmed milk is in such cases usually readily digested, and this we find in a natural state in asses' milk. Poverty in fat and abundance in sugar make asses' milk an invaluable nutriment, maintaining and cheering the life of many invalids. Many excellent rules are drawn from nature, and none more so than is to be found in the food which nature supplies for the nourishment of the infant. I consider the health of the child to be the surest and largest experience which enlightens us as to the right composition of solid and liquid food which man has to partake. This experience confirms the truth, that meat and bread cannot be taken without water; and that in the best nutriment of mankind the albuminous and fatty matters, the constituents of fat, the compounds of chlorine, and the salts, must be represented without exception.

"Whether food has a yet higher influence," says Forster, in his dissertation on the utility of the bread-fruit tree, "whether mind and heart may directly or indirectly be tuned by it, will be left to our grandchildren for discussion. We only know that gentleness, love, and sensibility of heart are the prominent traits of the people living on bread-fruit." And if we consider that, even now, the pastoral tribes are the gentlest, that the character of the beasts of prey is softened by getting accustomed to a mixed or a vegetable diet, why should it sound fabulous if we connect the noble tenderness of heart and pacific meekness of the pastoral tribes with the milk and the fruits upon which they live?

§ 72. **Coffee, Tea, and Chocolate.**—The general opinion that coffee, tea, and chocolate are beverages which, to a certain degree, may be substituted for each other, is based on a good chemical reason, for all three contain a nitrogenised basis, to which they owe some of their most important chemical properties. Tea and coffee even contain the self-same basis, denominated therefore indiscriminately thein or caffein. The basis of chocolate I will call cocoa-principle. The cocoa-principle, or theobromin, is richer in nitrogen than the thein, which latter very nearly corresponds in its composition with flesh-basis. In cold water, thein is only with difficulty dissolved, while of cocoa-principle but a small proportion is soluble even in hot water, in which the former readily dissolves.

While in tea the basis is combined with common tannic acid, in coffee it forms a salt with a peculiar tannic acid containing a greater proportion of nitrogen, which, together with tanno-caffeic acid, are united with potash into a so-called double-salt. Tanno-caffeic acid, when roasted, develops the agreeable smell of coffee.

Not only the same basis, but also two similar organic acids,—one contained in tea, the other in coffee,—increase the conformity between the leaves of the former and the beans of the latter.

Legumin, cellulose, gum, sugar, citric acid, in addition to oleine and to the peculiar palm-fat, which derives its name from being found in the fruit of several species of palms, accompany the organic acids and the thein of the coffee-beans.

But the tea-leaves, apart from the basis and the acids, are composed of albumen, cellulose, gum and wax, the green pigment of the plant, and the volatile oil of tea. This peculiar oil is the principal source of the aroma of tea, by which, in spite of the conformity between tea and coffee, it essentially differs from the latter.

The inorganic constituents of tea and coffee are, moreover, different. While in coffee, chlorine, phosphoric, and sulphuric acids are combined with potash, lime, magnesia, and oxide of iron; tea contains another inorganic acid besides, consisting of manganese and a large proportion of oxygen.

In the kernels of cocoa, of which chocolate is prepared, there are to be found, besides the cocoa-principle, stearine and oleine, cellulose, gum and starch, a red colouring matter, and a small proportion of water.

Chicory, so commonly used as a substitute or accompaniment of coffee, contains neither caffein nor any other peculiar constituent of the latter. No albuminous substance ever has, up to this time, been found in chicory. As albumen is not wholly wanting in any vegetable product, it must be present in chicory, though in a very small quantity. But the constituents of fat are represented in a larger proportion; for in addition to cellulose, sugar, and gum, it contains a pretty considerable quantity of a substance of the same composition as starch, which, by simply boiling in water, is transformed into sugar. Chloride of sodium, a compound of chlorine with ammonia (the so-called sal-ammoniac), sulphate and nitrate of potash, are its inorganic constituents.

As yet, therefore, no great importance as a nutriment can be attributed to chicory, nor any similarity with coffee. Unless a peculiar organic substance contained in it, but not yet exactly investigated, shall at a future time be proved to be peculiarly valuable, the infusion of chicory possesses no advantage over sugared water, to which a brown colour and bitter taste have been imparted; but, I repeat, we do not understand this bitter substance. Whilst, then, chicory cannot, on scientific grounds, be made out to be a true substitute for coffee, it has, on the other hand, been too partially investigated to justify an absolute condemnation.

§ 73. **Preparation of Teas.**—Roasted coffee differs from raw by its lighter weight and greater bulk. Several empyreumatic substances, produced by roasting, occasion the reddish or dark-brown colour, and the tanno-caffeic acid, altered by roasting, produces the aroma; the sugar loses a part of its amount of hydrogen and oxygen, and is thus decomposed into burnt sugar or caramel. In the infusion, the caffein and the acids, the gum and caramel, the melted fat and the salts, with legumin in a very slight proportion, are to be found.

Between green and black tea, erroneously so often supposed to be produced by different plants, a similar difference exists to that between raw and roasted coffee. The leaves are turned black by being dried at a higher temperature than that to which the green tea has been subjected. The latter is first brought into a withered condition by vapour, and then dried in iron kettles; while black tea is prepared by heating over an open fire. As heat exercises a decomposing action, black tea contains less tea-oil, less tannic acid, and less green colouring matter than green does. By the process of drying, however, a dark product of decomposition is formed, few traces of which are found in green tea, but a considerable quantity in black. In China, tea is not seldom coloured with curcume and indigo, or Prussian blue.

By the effect of the open fire, in black tea the albumen is more completely coagulated than in green; by this coagulation the tea-oil becomes disengaged. Partly from this cause the black tea has lost a greater proportion of its tea-oil than green; and for the same reason, tea possesses more flavour if infused with perfectly boiling water, which coagulates all the soluble albumen, and therefore dissolves the tea-oil with greater ease. But the tannate of thein, also, is only sufficiently extracted by boiling water; this compound is even separated at a low temperature; and hence the turbid appearance of a well-prepared infusion of tea when cooking, which everybody knows who has ever taken his tea out of a tumbler, as the Russians generally do. Thein and tea-oil, however, are the most important constituents of tea; boiling water is therefore an indispensable condition, if we wish to partake really of tea, and not of a brown solution of gum. The tea-leaves have only to be infused with boiling water, and after this the process of boiling must not be continued, or the tea-oil escapes, and the formation of a bitter solution of tannic acid takes place, a decoction which could as well be prepared from oak-apples. The first infusion contains four to six times more of the peculiar constituent of tea than the second.

Finally, the two principal kinds of chocolate are distinguished similarly to green and black tea. It is true, the cocoa seeds, of which chocolate is prepared, are always roasted. Besides the decomposed fat, an aromatic, empyreumatic substance of dark colour is formed from the starch and gum; but the proportion of the latter substance is larger in the more strongly roasted, dark-brown Italian chocolate, than in the Spanish, which, being less roasted, holds more starch and butter of cocoa in an unaltered state. The colour of the Spanish chocolate is brown-red, its taste not so bitter and aromatic as the Italian.

§ 74. **Nutritive Qualities.**—From its very large proportion of albumen, chocolate is the most nutritious of these three beverages; but, at the same time, the most difficult of digestion from its quantity of fat. But as its aromatic substances strengthen the digestion, a cup of chocolate is an excellent restorative and invigorating refreshment even for weak persons, provided their digestive organs are not too delicate. Cardinal Richelieu was indebted, in his later years, for his health and hilarity to chocolate.

Tea and coffee do not afford this advantage. Albumen in tea-leaves, and legumin in coffee-berries, are represented in very scanty proportions, and still more scantily in their infusions: for while in the former the albumen is coagulated by boiling water, in the latter the legumin is prevented from being dissolved by the lime with which it is combined.

It is true that coffee and tea have been praised, even by chemists, as nutritious substances, at a time when "nitrogenized" and "nutritious" were considered identical terms. Since then, however, we have learned that, as restoratives for the body, not the elements but the alimentary principles are to be taken into account. The latter appellation cannot be ascribed to thein, which is excreted again as urea with surprising rapidity. To this swift transformation tea and coffee owe their diuretic action, which is considerably assisted by the warm water of the infusion; the kidneys attract the urea, with which theim charges the blood.

Tea and coffee, though of themselves not difficult of digestion, tend to disturb the digestion of albuminous substances by precipitating them from their dissolved state. Milk, therefore, if mixed with tea or coffee, is more difficult of digestion than if taken alone; and coffee alone without cream promotes digestion after dinner, by increasing the secretion of the dissolving juices. No Italian takes cream with his coffee after dinner.

The volatile oil of coffee, and the empyreumatic and aromatic matters of chocolate, accelerate the circulation, which, on the other hand, is calmed by the tea-oil.

Tea and coffee excite the activity of the brain and the nerves. Tea increases the power of digesting the impressions we have received; "we become disposed for thoughtful meditation, and, in spite of the movements of thought, the attention can more easily be fixed upon a certain object; a sensation of comfort and cheerfulness ensues, and the kreatine activity of the brain is set in motion; through the greater collectedness and the more closely confined attention, the thoughts are not so apt to degenerate into desultoriness. Educated persons will assemble to tea for the purpose of investigating a certain subject by a regular conversation; and the higher spirits produced by the tea, tend to secure with more facility a successful result. If tea is taken in excess, an increased irritability of the nerves takes place, characterized by sleepiness, by a general feeling of restlessness, with trembling of the limbs. Spasmodic attacks even, with difficulty of inspiration in the cardiac region, may arise. The volatile oil of the tea produces heaviness in the head, and, in fact, a real tea-intoxication, first manifesting itself in dizziness, and finally in stupefaction, takes place. Green tea, which contains much more of the volatile oil than black, produces these obnoxious effects in a far higher degree than the latter."

While tea principally revives the faculty of judgment, and adds to this activity a sensation of cheerfulness; coffee acts also on the reasoning faculty, but without communicating to the imagination a much higher degree of liveliness. Susceptibility to sensuous impressions is intensified by coffee; the faculty of observation is therefore increased, while that of judgment is sharpened, and the enlivened imagination causes the perceptions more quickly to adopt certain forms; an activity of thoughts and ideas is manifested; a mobility and ardour of wishes and ideals, which are more favourable to the shaping and combination of already premeditated ideas, than to a calm examination of newly originated thoughts.

"Coffee taken in excess causes sleeplessness and a state of excitement similar to intoxication, in which images, thoughts, and wishes rapidly succeed each other. A sensation of restlessness and heat ensues, together with anxiety and dizziness, trembling of the limbs, and a strong desire to go into the open air. Fresh air is commonly the best means of throwing off this condition, which, whilst it continues, exercises a really consuming power over man."

In Constantinople, the first coffee-houses used to be called schools of knowledge. Poets and philosophers assembled in these schools; their discussions and judgment alarmed even the ruling authorities; the clergy made Mourad II. afraid of these assemblies; and priestly dread, the faithful ally of overweening tyranny, closed the "schools of knowledge." In the seventeenth century, the coffee-houses in London had a similar fate; but the habit grew too strong for the State. Social revolutions are not hindered by force, because they are advanced by force.

§. 75. **Wine, Beer and Spirits.**—The immense variety of intoxicating liquors forms a striking illustration of the pains which men have always taken to excite the brain. Alcohol is the magic name with which the action of all these liquors is associated. Alcohol, a volatile substance, composed of carbon, hydrogen, and oxygen, may be produced from sugar; and thus, wherever the chemist finds an abundance of sugar, this discovery is ever closely followed by the proposition to transform the saccharine substance into alcohol. But long before the chemist could give his directions, palm-wine was in favour in Babylon; the Phoenicians and Greeks drank their wine, which their poets celebrated in songs. The Tartar sought intoxication in his kumiss, and Ossian praised the mead as "the power and glory of the shells,"—the drinking-vessels of the Caledonians. In the juice of the palms and grapes, in milk and honey, in corn and potatoes, as well as in many fruits, this fermentable substance was found before the principle of fermentation and the nature of the process had even been divined.

Now we know that sugar is the ferment, and that all intoxicating liquors must contain either sugar itself, or a constituent of sugar. When potatoes furnish alcohol, the starch has previously been transformed into sugar; and before the kumiss is produced from milk, the sugar of milk has been transmuted into grape-sugar; for the latter only is directly fermentable.

Starch and gum, cane-sugar and sugar of milk, are only indirectly so, being turned by the action of acids into grape-sugar. An albuminous body stimulates the fermentation: it is yeast. At a high temperature, sugar ferments under the influence of yeast. Air-bubbles rising in the juice, and a vinous smell, betokens that the effect of this agent has begun. The air is carbonic acid, and the smell is occasioned by the spirit of wine, called by chemists alcohol, if free from water. The sugar is transformed into alcohol and carbonic acid, upon which the fermentation ceases.

Diluted alcohol, or spirit of wine, is the intoxicating substance from which beer, wine, and brandy derive the name of spirituous beverages. Spirit of wine is contained in all fermented liquors.

The proportionate quantity only is different; for while the lightest beer scarcely contains more than one-hundredth part, and the strong English ale scarcely more than eight-hundredths of alcohol, in wine its proportion rises to from seven to twenty-six per cent, and in the strongest brandy this quantity is surpassed twofold. In the latter the alcohol of the fermented juice is concentrated. A high temperature evaporates the spirit of wine, which is collected in the vessel of a still. The name of brandy (burnt wine) attests the assistance of fire, by which it was carried over into the vessel.

First of all therefore, beer, wine, and brandy are different in their respective strengths, which is due to their proportionate amount of alcohol. The several concomitants dissolved in spirit of wine explains the rest.

§ 76. **Alcohol in Wines and Beer.**—The weak alcoholic solution of beer contains nearly the same proportion of albumen as is found in fruits, some sugar and gum, malic acid from the hop, sometimes also some lactic and acetic acid, products of decomposition of the sugar and alcohol; and in addition to these a peculiar constituent of the hops, soluble in water, and consisting of carbon, hydrogen, and oxygen, which from its bitter taste is called the bitter principle of the hop, together with some essential volatile oil of hops. The combinations of potash, lime and magnesia with sulphuric and phosphoric acids are associated with carbonic acid, which is contained in the beer the more abundantly, the smaller the quantity of sugar is which had undergone fermentation when the beer was put into the barrel. A frothy beer is often prepared by a certain addition of sugar in boiling, and better still by adding sweet fruits—raisins for instance—in which both the ferment and the principle which promotes fermentation, sugar and yeast, are present. Slightly dried malt gives to the beer a more or less brown colour.

In wine, more alcohol and less water than in beer are combined with sugar and gum, with resin and colouring matter, acids and salts.

Even the white wines contain a peculiar colouring matter, yellow-like oil, whitened by acids, browned by alkalies. The yellow tint of white wines, which after having been frozen have thawed again, is produced by the partial disengagement of the acid salts, which caused the lighter colour before the wine had frozen. The different kinds of grapes of a light or high yellow or copper colour, of a blue, red, or dark brown tint, produce as many different colours in wine. The number of the peculiar colouring matters is probably smaller, as the acids and salts of the grapes alter the colour. By the action of acid salts, the blue colouring matter turns red.

The particular taste distinguishing very old Rhine wines is occasioned by wax, which is united with the colouring matter.

The acids of the wine are the acids of the grape. Tartaric and malic acids—perhaps, too, citric acid—are sometimes accompanied by the tannic acid of the husk and by grape acid, being of the same composition as tartaric acid, with which it is associated in several kinds of grapes.

As the fermentation has not ceased when the wine is put into the casks, all wines contain a certain proportion of carbonic acid; and the strong effervescence of sparkling champagne depends upon the intentionally interrupted fermentation, which continues in the bottles.

The following are the salts contained in wine:—Cream of tartar, or acid tartrate of potash; tartrate of alumina, combined with tartrate of lime into a double salt; malate of lime; lime combined with phosphoric and carbonic acids, in addition to magnesia, iron, and manganese. In red wine there is a greater proportion of salts than in white; in both of them the alcohol, augmented by the fermentation which still goes on in the casks, separates a part of the salts.

In all wines a peculiar ether is contained, upon which the odour generally depends. In this ether the common salt-ether exists, in combination with a peculiar organic acid, which I may call the acid of wine-ether. The perfume, or "bouquet," is something different from the odour of wine produced by the wine-ether. This bouquet is extremely various. It distinguishes the Rhine-wine, but in several wines it is not to be found at all. It is also produced by different kinds of ether, by ether combined with butyric, or valerianic, or acetic acid. The latter compound is said to be found in most of the Bordeaux wines or clarets. Like ether itself, which in its composition differs very little from alcohol, but surpasses the latter in volatility, the combinations of ether with organic acids are very volatile. Wine-ether and the bouquet are therefore recognised by smell.

The colouring matter and bouquet, the acids and salts, cause, by the difference of their composition, the variety of wines. The strength of wine depends upon its proportion of alcohol, and the sweetness of sack upon that of sugar. Spirits are obtained from corn and potatoes, from lees of wine and juniper-berries, from sugar and rice, from milk and fruits. The spirit of corn, or whiskey, contains wine-ether and margaric-ether, oil of grain, and potato-spirit oil, which increases the pungent odour of spirits. Potato-spirit contains the same constituents, with the exception of oil of grain and margaric-ether. Brandy, or cognac, is a mixture of water and alcohol with wine-ether.

and acetic-ether. The inferior sorts of cognac contain also some potato-spirit oil. The fragrance of rum, which is prepared from the juice of the sugar-cane, is produced by a combination of butyric acid and ether. The molasses which remain after the preparation of sugar from the juice of the cane yield the finest rum, called tafia or ratafia. Arrack is obtained from rice, gin or Geneva from juniper-berries, kumiss (as already stated) from milk, and mead from honey.

§ 77. **Alcohol in Spirits.**—A good beer is as nutritious as fruit; the nutritious quality of wine is scarcely equal to that of sugared water; and spirits, in their proportionate amount of nutritious matter, do not even bear comparison with sugared water. Is it, therefore, a mere illusion that spirit compensates for the scanty food of the poor? And is the zeal, therefore, justifiable which attempts to check its use as an intoxicating poison—a destroyer of domestic peace and well-being? Such questions I often hear. Even medical men, occupied with the study of human physiology, have answered them in the affirmative; for my part, I shall reply to these questions by facts.

Alcohol, the essential constituent of spirits and the most important substance in beer and wine, is not transformed into an essential constituent of the blood. It does not, therefore, effect any direct restitution, nor deserve the name of an alimentary principle. Still, it passes into the blood. By the oxygen we inhale it is burnt in the blood into acetic acid and water, and finally into water and carbonic acid. But the oxygen, which decomposes the alcohol, is withdrawn from the albuminous and fatty substances of the blood. Alcohol, from its greater combustibility, protects these constituents of the blood from being burnt. And if, in addition to this, both special experiment and ordinary experience prove that alcoholic beverages diminish the quantity of carbonic acid we exhale—apparently from a great part of the inhaled oxygen combining with the hydrogen of the alcohol into water—there is a twofold argument for believing that alcohol moderates the combustion of the constituents of the blood, and therefore diminishes the first cause of the need of restitution.

He who possesses little, must spend little, if he wishes to retain as much as another who unites abundance with liberality. Alcohol may be considered a savings-box of the tissues, but let the reader understand this expression rightly. He who eats little, and drinks a moderate quantity of spirit, retains as much in the blood and tissues as a person who eats proportionally more without drinking any beer, wine, or spirits. Hence it follows that it would be cruelty to deprive the working man, who earns his frugal meal by the sweat of his brow, of those means by which he is enabled to prolong the nourishment yielded by his scanty food. Or are we to abolish a custom which renders abuse possible, to degrade man by demanding of him to renounce an enjoyment, in order that he may not succumb to a bestial instinct? The monk who requires the vow of chastity does not do greater violence to the true nature of man, than dose the physician who would prohibit spirits because some men are drunkards. Goethe has given to the new contemplation of the world the noble watch-word—"*Memento vivere.*" He who preaches the renunciation of spirits transfers us to the christendom of the middle ages, which by its motto of "*Memento mori,*" has stifled the fairest blossoms of humanity.

§ 78. **Fermented Liquors.**—Fermented liquors, taken in moderation, increase the secretion of the digestive juices, and promote the solution of the food. Taken in excess, they cause induration of the stomach; which destroys, together with the digestive powers, the formation of blood.

Beer, wine, and spirits accelerate the circulation, or, as people say, heat the blood. This acceleration is produced in a higher degree by wine than by beer; more by spirits than by wine, not merely because wine contains a greater proportion of alcohol than beer; and spirits still more than wine. But in wine and spirits the different kinds of ether, the oil of grain and the potato-spirit oil, all tend to quicken the circulation of the blood. The glowing cheeks and glistening eyes are produced by the capillaries of the cheeks and eyeballs being more filled, in consequence of the increased activity of the heart.

Together with the blood, the alcohol passes into the brain, which beyond all other organs is affected by its action. Spirituous liquors stimulate the imagination in particular. "In consequence of this faculty," it is said in my "Physiology of Food," "the association of ideas is facilitated and the memory sharpened. The susceptibility of the senses is also rendered more keen; the impressions are quickly and distinctly perceived. The judgment is formed with greater ease, as, from the lively idea and the excited memory, the facts from which it is derived are brought nearer together. Hence a frequent and surprising clearness and precision of judgment in matters not requiring a long and close examination. We speak foreign languages with more than usual adroitness. The facilitated movements of thought, the versatility of ideas, is associated with greater ease in the movement of all the voluntary muscles; the voice becomes fuller and stronger; the weariness and relaxation following the exertions of the body vanishes. Thus arises a feeling of comfort and delight, of increased strength and freshly-armed courage, scaring away ill-humour, sorrow and fear. The affairs of others find a greater sympathy and forbearance, which in return are likewise expected of those around us. We, therefore, talk with a greater self-confidence of ourselves; and not only of what has already been performed, but even future undertakings are spoken of with unreserved self-complacency.

"When wine or other spirituous liquors are taken in excess, hallucinations of the senses ensue; objects appear to the intoxicated person obliterated, blurred, or double; dark spots resembling flies and sparks appear before the eyes; there is ringing in the ears; he cannot hear distinctly his own voice nor the voice of others; crying instead of speaking, and involuntarily singing out of tune. At the same time the imagination produces uncertain, variegated, unsteady images, combined without regularity; the memory refuses its functions in the very act of speaking; the intoxicated man forgets what he intended to say, and thus the judgment is troubled and confused. There follow the ebullitions of an unjust passion, and a sensibility to opposition, which is so much the oftener irritated as the disturbed action of the brain, overloaded with alcohol, impairs the correctness of the judgments.

"Excessive indulgence in wine and all other spirituous liquors causes sleep; if increased to a complete intoxication, the mental functions are disturbed to such a degree, that a condition of temporary insanity supervenes; the senses become blunted; the imagination produces the most various and irregular images, which the judgment is unable to examine, distinguish, or combine; all self-possession vanishes; at length even consciousness is lost, the intoxicated man becomes giddy, and finally falls into a profound slumber.

"But before this a sensation of lassitude and exhaustion arises; the muscles lose their elasticity, the features become flabby, the angles of the mouth are depressed, the pupils widen, and urine and excrements are involuntarily voided. The muscular coat of the stomach, urged at the same time by a pressure of the diaphragm and the abdominal muscles, often acts in an inverse direction; violent vomiting is a common phenomenon. Even the respiratory muscles are weakened, and often act irregularly, occasioning sighs or groans; the pulse becomes languid and slow. In addition to this, an increasing reluctance and uncertainty in all voluntary movements is observed; the tongue stammers or speech entirely ceases, the head sinks, the arms hang down, the legs cross each other when walking, the drunken man staggers, his paces cannot maintain a steady direction, he totters, and falls."

I hasten from this disgusting picture to describe, in the words of Hettner, the condition of a more moderate inebriation, intermediate between the former and perfect sobriety. "A beautiful, vigorous, full body," says Hettner of an ancient work of art, "in the first freshness of a still juvenile manhood, with great, firm, swelling limbs; there he lies at his ease, partly leaning against a rock, his limbs partly outstretched. In this state of happy inebriation he has chosen this place of rest; now he has fallen asleep—arms and legs are hanging down—in his features are the indescribable expression of a half-intoxicated slumber. In a confused dream, the wakeful imagination is still dwelling with delight upon the past hours; but the weary, unnerved limbs cannot follow this sweet ecstasy. The eyes closed, the mouth widely open, this sleep is the state of that 'seedy' half-slumber, in which the internal heat and a thirst panting for water urge to awake; while the limbs, craving repose, desire to continue sleeping, and the mind is unconsciously apprehensive of the dreary, unrefreshed awakening."

ON CONDIMENTS.

§ 79. **Common Salt.**—When Cook and Forster in 1772 visited the island of Otaheite, the natives were astonished at the crew at dinner dipping every piece into "a white powder." At the same time they took their fishes and meat with a sauce of sea-water containing common salt in abundance. It was a similar case to that of the Greeks and Romans, who were well acquainted with the alcohol in wine, but did not know the art of obtaining it pure and concentrated by the process of distillation.

The addition of common salt to the food, whether in the form of sea-water, as a product from this, or of rock-salt, as dug from the mines, is usual everywhere. We must not wonder at this, seeing that common salt is contained in our blood in as great a proportion as it is scarce in the natural aliments; for in animal food the blood and cartilages are provided with the greatest proportion of common salt, and these are just the parts of flesh-meat which are taken in the smallest comparative quantity. In our vegetable food, potash so generally predominates over soda, that only a few plants of the sea-shore form an exception by their large proportionate amount of soda. Some vegetable aliments, turnips for instance, often contain no soda at all.

The addition, therefore, of common salt, consisting of chlorine and soda, is usually an indispensable necessity; and as the vegetable aliments contain a smaller proportion of common salt than animal, the latter is generally mixed with less salt than the former. Hence, it becomes possible to some nations, as the Samoyedes, the Kamtschatdales, and some Indian tribes of North America, to eat meat or fish without any addition of salt. The greater the proportion of blood contained in meat, the more easily the addition of common salt may be dispensed with.

The common salt, however, of our kitchens is not a pure chloride of sodium. Rock-salt is generally the purest, as containing only some traces of chloride of potassium and chloride of magnesium, in addition to a somewhat greater proportion of sulphate of lime. But with bay-salt a much greater proportion of chloride of magnesium and sulphate of lime, with a not inconsiderable quantity, besides, of sulphate of magnesia, or Epsom salts, are mixed. In common salt prepared from sea-water, chloride of potassium is entirely absent, or only small traces of it are found, which sometimes coexist with as small a proportion of iodine.

Common salt is as digestible as nutritious; for water dissolves it with the greatest ease; and while no tissue of the human body can exist without common salt, the blood and the cartilages cannot keep up their regular composition without a considerable proportion of it.

If, besides, we bear in mind that common salt promotes the digestion of the albuminous substances, and that the scantily soluble fats, when settled, become less difficult of digestion, the chloride of sodium appears to be the most important addition to food, rightfully meriting to stand at the head of the series of condiments. On account of its greater proportionate quantity of chloride of magnesium, sea-salt dissolves the albuminous substances more readily than rock-salt; for the temperature of the body is of itself sufficient to transform the chloride of magnesium into hydrochloric acid and magnesia; and every diluted mixture of hydrochloric acid and water is able to dissolve the albuminous substances.

Common salt is very useful for the preservation of aliments by attracting their water, which more than any other constituent occasions putrefaction; yet it is important to know that meat by being salted loses a part of its best alimentary principles. Together with the water of the flesh, albumen and kreatine, the lactic acid and the salts are extracted by the common salt. The brine thus formed is thrown away, and with it a part of the most soluble and most important substances of the flesh. This loss is somewhat compensated by the fibrine of salted meat being more soluble than fresh muscular fibres, as well as by the use of bread and vegetables containing chloride of potassium and phosphate of potash, which have been extracted from the meat, and substituted by the common salt.

By the excretions common salt is abstracted from the blood. In the same proportion as the urine and the excrements, the mucus and the perspiration, the tears and the horny substances have deprived the blood of common salt: the blood nourishing the nerves of the tongue is poorer in this salt. This is the reason why unsalted food tastes insipid. And even here the necessity of a law governs the seeming play of arbitrariness. It is the strictest consequence of cause and effect which unites the taste of the nutriment with the reception of the right alimentary principles. In former times, it was conceived to be a result of wise calculation that just those aliments should have a better taste which contain the matters most requisite for the blood, and regarded as an inherent inclination in man to salt his aliments. "If it is considered more edifying," says Charles Snell, "to conceive of the Creator, so to speak, to be like a watch-maker who calculates exactly, than to regard Him as the organic, acting, productive reason of nature, we will not dispute any more." But then we renounce all certainty of knowledge, for it can scarcely be proved that it is part of the original tendency of our being to supply our blood with common salt; but the connection between differently mixed blood and differently feeling nerves, is perspicuous and evident.

§ 80. **Butter and Olive Oil.**—In milk left undisturbed for some time, cells containing butter rise to the surface. From the stratum thus formed, by beating or stirring at a higher temperature, butter is formed. The force of stirring, supported by a moderate heat, causes the cells in which the butter has been included to burst; the disengaged fat collects into flakes, conglomerating into larger masses.

This origin explains why butter cannot consist of pure fat; the proportion of the fat in it does not amount to more than from six-seventh to four-fifths of the whole, one-seventh to one-fifth consisting of water combined with some caseine and sugar of milk. The fat of the butter, however, is for the greater part real butter-fat, or butyrine. By this name the chemist designates a fat peculiar to butter, which for a long time was supposed to be the only one present in it; but at the most this amounts to but two-hundredths of its weight. Butyrine becomes liquid at a very low temperature. It consists of glycerine and butyric acid, which is volatile in a free state, and possesses strongly the characteristic odour of butter. Three fatty acids besides, all volatile in an uncombined state, are, like butyric acid, united with glycerine, and therefore without odour in the fresh butter—namely, the caseic, sudoric, and capric acids.

The other fats of butter are oleine and margarine. As oleine is more fluid than the oil of almonds, the solidity of butter depends exclusively upon the margarine. At a very low temperature the oleine coagulates, and this partly produces the greater firmness of butter in winter; which is also partly to be explained by the fact that in the latter, oleine and margarine are contained in the proportion of one to three; while in the butter made in summer, the inverse proportion exists. Margarine melts at the temperature of 118° Fah., and therefore winter-butter also liquefies at a higher temperature. But while melted butter is cooling again, the liquid fats separate from the coagulating margarine, and hence the butter assumes a taste disagreeable to most persons. But much more so is the decomposition of real butyrine, and the other neutral fats composed of the volatile acids and of glycerine; for if butyric, caseic, sudoric, and capric acids become disengaged, the butter assumes an offensive, pungent odour, and an acid taste, liked only by the Icelanders. The butter is then called rancid.

This decomposition is produced by the caseine and the water of the butter. Common salt, intermingled with butter, has the advantage of attracting the water and causing the caseine to be ineffectual; while by the process of melting the caseine is skimmed off from the surface of the butter as a gray scum, and the water evaporates. For preservation, therefore, butter is generally melted and salted.

Olive-oil is commonly used as a condiment of salad. It contains nearly three-fourths of oleine and very little more than one-fourth of margarine. In the oil of almonds, the oleine is more than three-fourths, and the margarine rather less than a quarter, of the whole.

Although these oils do not exhibit any neutral fats with fatty, volatile acids, yet they have the property of becoming rancid like butter; for by the process of decomposition both caseic and capric acids are formed out of oleic acid. This transformation, however, caused by the influence of oxygen, takes place only very slowly in olive-oil, as consisting entirely of mere fat; and olive-oil, as well as the oil of almonds, may be preserved for a very long time without becoming in the least rancid.

§ 81. **Digestibility of the Fats.**—Only that small proportion of the fats which can be saponified by the alkali of the bile, the pancreatic and intestinal juices, is to be considered soluble in the digestive juices. By far the larger part is so finely subdivided by the pancreatic juice and the bile, as to be able to penetrate the walls of the lacteals and the veins. Moreover, with respect to this fact, the fats are to be considered as difficult of digestion; they are far inferior to the constituents of fat in the capability of being dissolved, but superior to them in the greater conformity with the actual constituents of the blood.

The observation, however, which was made a little time ago, that starch is much more easily transformed into fat if taken with some fat than if alone, proves butter, as well as olive-oil, to be particularly useful. In bread and butter, therefore, we have the satisfaction of discovering a fresh and striking illustration of the truth, that ancient experience often leaves to science nothing to do but to establish and explain its laws.

Quite unjustly, therefore, are butter and oil said, without qualification, to be difficult of digestion; and the poor man has adopted the best substitute when he tries to supply the want of butter by grease. Butter on bread is a necessity recognized by impartial science; salad without oil is digestible only by herbivorous animals.

§ 82. **Cheese.**—Cream, milk, skimmed milk, and whey furnish severally cream-cheese, rich, meagre, and green cheese. In its abundance of fat, cream-cheese is the richest; while green cheese, prepared from whey, which contains only a very small proportion of fat, is the poorest of all.

The principal constituent of cheese is the caseine of the milk; according to the means by which this caseine has been coagulated, whether by rennet or by the lactic acid formed in the milk itself, the cheese is called sweet or sour-milk cheese. The action of the rennet (*i.e.* the stomach of calves) is aided by a warm temperature; a high temperature causes cheese to become hard, just as the abundance of fat makes cream-cheese soft.

In milk the fat closely adheres to the caseine; in cheese, therefore, the proportion of fat exactly corresponds with the relative quantity of butter. In addition to butter, the salts of the milk, and a part of the sugar of milk, are to be found in cheese. In real cheese the caseine and the butter are partly decomposed. Of the caseine is formed a nitrogenized substance, the "lincin," which I will denominate "cheese-white," as it crystallizes in glittering white threads, and as this word recalls the chemical technical expression. Besides this substance, an oily acid is developed, not very readily soluble in water, which corresponds with the peculiar acid of the root of valerian, not only by its penetrating odour and its strong, pungent taste, but also in its composition and all other qualities; it is therefore called valerianic acid. Some butyric acid besides is formed of the caseine; and hence we find in cheese which is several months old, more butyric acid than in fresh.

But the greatest proportion of the butyric acid originates from the decomposing butyrine; and the same is the case with the caseic, sudoric, and capric acids, associated in cheese with the valerianic acid.

A part of the whey is very often retained in the cheese; the sugar of milk of the whey is decomposed into butyric and carbonic acids, and the latter causes the holes to be observed in the Swiss and American cheese.

The odour and taste of the cheese is produced by the fatty acids, as well as by the valerianic, which is similar to them. Common salt decisively checks the formation of these acids from caseine and butter. The taste of many Dutch cheeses is less aromatic, from their being mixed with an abundant proportion of common salt; and as the decomposition of caseine and butter increases with their age, the odour and taste of the cheese is much stronger the longer it has been kept.

Though butyric acid may originate from three different substances of the milk—namely, from butter, sugar, and caseine—yet the butter contributes by far the greatest proportion of volatile acids. A rich cheese, like that of Limburg, smells therefore much stronger than the poor Marzalino, or the still poorer green cheese.

§ 83. **Digestibility of Cheese.**—In speaking of the fat contained in confectionery, I have already remarked, that the digestion of it is the more difficult the more it has been transformed by a high temperature into its products of decomposition. The abundance of these products of decomposition is the cause of the difficult digestion which characterizes cheese itself. But cheese impels the digestive glands to a greater activity; a greater quantity of saliva and bile, of gastric and pancreatic juices, is secreted and carried into the digestive canal; and hence the cheese, notwithstanding its difficult solubility, may be considered, in a restricted degree, as promoting digestion. And not for this reason alone; for the caseine, while in a state of decomposition, promotes also the transformation of starch and sugar into lactic acid and fat. Like butter, cheese increases the digestibility of the bread; and dry bread is, therefore, less nutritious than bread with butter or cheese.

With regard to the inorganic alimentary principles, the cheese made from sweet milk is superior to that from sour; in the latter the earthy salts have been dissolved, while the phosphate of lime, contained in milk, is abundantly represented in the former. Only where the breeding of cattle flourishes, and milk is produced in abundance, cheese is prepared; where cheese is prepared, meat cannot be deficient; a rich blood produces, together with the vigour of the muscles, the noble mind and the ardent courage of liberty. This is the association of thoughts which made John von Muller say, that liberty thrives where cheese is prepared.

§ 84. **Vinegar.**—That which renders vinegar so favourite an addition to food is a peculiar acid, consisting of carbon, hydrogen, and oxygen, formed from alcohol by the absorption of an additional quantity of oxygen. From *acetum*, the Latin name of vinegar, this acid is called the acetic, and is to be obtained from all spirituous beverages. But as alcohol yields in addition to the acetic acid a quantity of water, both malt and wine-vinegar contain, in proportion to the acetic acid, more water than is to found in either beer or wine, in proportion to the quantity of alcohol. Of wine, or French, vinegar, about one-twentieth in weight consists of pure acetic acid. In an inferior vinegar this acid does not even amount to more than one-fiftieth to one five-and-twentieth in weight.

Vinegar, therefore, is always a considerably diluted solution of acetic acid, containing in addition a small proportion of albumen and sugar, of gum, and of several other organic substances, especially of some colouring matters which differ according to the liquor from which the vinegar has been prepared. Thus, in wine-vinegar there is some acid tartrate and sulphate of potash to be found; and in wine and fruit-vinegars, a proportion of tannic acid, to be attributed to the husks and skins of the fruits. And acetic-ether, passing over into wine-vinegar from some kinds of wine, communicates a fine agreeable fragrance to the vinegar.

If the acetous fermentation has not entirely ceased, the vinegar still contains a small proportion of alcohol, which, by a further accession of sugar, becomes decomposed into water and acetic acid.

In order to increase the sour taste of the vinegar, the admixture of one-thousandth part of sulphuric acid is permitted in England. If added in a larger quantity the sulphuric acid is injurious.

§ 85. **Dissolving Action of Vinegar.**—The vinegar assists digestion. With the exception of legumin it dissolves the albuminous substances, transforming in a short time even the glutine and the fibrine into a gelatinous mass. Hence, vinegar and butter are useful concomitants of fish; and vinegar promotes, as I have before mentioned, the digestion of meat.

As acids are capable of transforming cellulose and starch into sugar, the vinegar added to salad is likewise to be regarded as an admixture promoting digestion. Thus, in the majority of cases the use of vinegar is a custom founded on good reasons. Only in soups of peas, beans, and lentils, vinegar is to be rejected, as by it, even if added in excess, the legumin is brought into an undissolved state.

The dissolving action of the vinegar upon the other albuminous substances goes even as far as to the blood. Beverages containing vinegar have a dissolving effect on blood, and are cooling; and in milk the proportion of caseine-cells, containing the butter, decrease if the mother takes much vinegar.

And because of this solution of the most important constituents of the blood, manifesting itself by a greater liquefaction, it would appear an unpardonable frivolity, or a lamentable ignorance, in young girls to endeavour from vanity to produce by means of vinegar an artificial thinness; only too often in attaining their aim they incur dangerous and deeply-rooting diseases, which deprive them of their more beautiful maiden bloom.

§ 86. **Sugar.**—Sugar has a similar history to that of alcohol and common salt. As many fermented beverages were known before the art of distilling, and the salt taste of the sea-water before the art of inspissation by boiling or crystallizing; so honey and sweet juices were familiarly known before the sugar which produces their sweet taste was extracted. It was not until the fifteenth century that the inspissation of the cane-sugar was learned; and it was much later before this process was carried to perfection.

Not only, moreover, has the method of preparing the sugar made great advance in later days, but the knowledge of the sources whence it is derived. The temperate zone possesses in the red-beet a substitute for the sugar-cane, though far inferior to it; and for the same purpose the sugar-maple is used in North America. Although the red-beet, the sugar-maple, and many other plants possess the same description of sugar as the cane itself, no other plant has been found equal to the sugar-cane; and the denomination of cane-sugar will maintain itself as descriptive of the sweetest kind of sugar. Cane-sugar is sweeter, and poorer in hydrogen, than grape-sugar, which is distinguished from the former, and from sugar of milk, by its direct capability of fermenting. Acids, however, transform the sugar of milk as well as cane-sugar into sugar of grapes; and hence, the two former can indirectly be brought into a state of fermentation.

By boiling with lime, cane-sugar is purified; for the saccharine vegetable juice contains a portion of soluble albumen, which is coagulated by this process, and then skimmed off. A liquid is thus formed, containing uncrystallizable sugar, consisting for the most part of the brown syrup of commerce, called molasses or treacle. In addition to this liquid, crystals of sugar are obtained, which, while depositing themselves, become mixed with uncrystallizable sugar, and represent the brown, the raw-sugar, or Moscovado. In a purer state of its crystalline grains, the cane-sugar is called "loaf" or "lump-sugar;" while sugar-candy consists of regular and larger-sized crystals, formed by a slower process. A part of the lime enters into combination with the sugar; and the Moscovado, particularly, is mixed with some phosphate of lime, and a viscous substance, probably gum.

In honey we find cane-sugar, an uncrystallizable kind of sugar, a small proportion of grape-sugar, and "mannit," or manna-sugar. The latter is distinguished from the other kinds of sugar by not being fermentable, and by containing a smaller proportion of oxygen than hydrogen; these two elements are present in the other sorts of sugar just in the same proportion as that in which they are contained in water. With these different kinds of sugar there is, in honey, most probably associated some lactic acid, formed by the decomposition of the cane-sugar, and some wax which possesses a great similarity with the fatty substances.

§ 87. **Nutritive Qualities of Sugar.**—As by salts and acids, so likewise by sugar and honey, is the quantity of the digestive juices increased, and the digestion promoted. And the sugar, while being digested, enriches the gastric juice with a substance which assists in dissolving the aliments; for the sugar, on coming into contact with the saliva, has been partly transformed into lactic acid, which acts upon the alimentary principles in the same manner as does the hydrochloric acid of the gastric juice.

For this reason, sugar at once appears infinitely better than its reputation. Since the composition of the milk has been recognised, the sugar ought to have been acquitted of the bad repute which adhered to it for many centuries. A slander always leaves something behind; and even to the present time the popular belief that sugar injures the teeth, is as widely spread as, on the counter testimony of both experience and science, the opposite doctrine ought to be: for the teeth of the negroes in the West Indian colonies are of a bright white; and that which is thus proved by a whole community remarkable for the abundance of sugar consumed among them, the example of many individuals nearer home amply confirms. Phosphate of lime is the chief constituent of the bones and teeth, but not before adult age; and an increase of the phosphate of lime is the essential characteristic of the development of the bones of children. Lactic acid dissolves the phosphate of lime of the food; and as sugar indirectly supports this solution, it facilitates the conveyance of the lime to the teeth. To this it must not be objected that sugar causes pain in a hollow tooth. Like sugar, a thousand other substances irritate the nerve; but who seriously believes that that is necessarily injurious to the healthy, which gives pain to the diseased?

The prohibition of sugar to children, therefore, is indefensible. Sugar is not dangerous to the teeth, but, on the contrary, assists in providing them with lime; it is useful to the stomach, if it does not, by being taken in excess, produce too great a quantity of lactic acid. Beware, therefore, of confectionery embellished with poisonous colours; but leave to the little ones their pleasure, and to the Christmas-tree its charm!

§ 88. **Spices.**—Under the name of spices I shall comprise mustard and caraway seeds, common and Spanish pepper, cinnamon and cloves, nutmegs and saffron. In addition to albumen and wax, cellulose and gum, starch and resins, acids and salts, which manifest unimportant differences with respect to their proportionate quantity and properties, all these spices contain a volatile oil of a pungent odour, and an acrid or aromatic taste.

It is only in the mustard, as we take it, that this oil is a product of fermentation. Just as the ferment of almonds (emulsine) transforms the principle of almonds (amygdaline) into volatile oil of bitter-almonds, so a peculiar ferment of the black mustard decomposes a certain constituent of the latter, which is not to be found in the white mustard, into the volatile oil of mustard, which contains, besides carbon and hydrogen, a proportion of sulphur and nitrogen. Of a light yellow colour and a pungent odour, the oil of mustard is soluble only in a large proportionate quantity of water. To this oil the mustard owes its peculiar taste; the mother-body of the oil of mustard is of a bitter taste. The black mustard contains a portion of stearic acid and two other fatty acids; which last are likewise to be found in white mustard, but without stearic acid.

The oils of the different spices above enumerated are to be found, ready formed, in the vegetable substances; rather aromatic than acid, they consist partly of carbon and hydrogen, and partly of a combination of these two elements with oxygen. With fatty oils, the volatile are by no means to be confounded. The latter, though scantily soluble in water, are not entirely insoluble in it; cannot be saponified with alkalies; and are especially remarkable for their disposition to turn into resins by the absorption of oxygen. There exists no fat without oxygen, while several of the volatile oils contain nothing of this element.

Cloves are furnished with the greatest proportion of volatile oil; while its relative quantity in the more acrid nutmeg scarcely amounts to one-third, in the very acrid Spanish pepper not even to one-fourth, in the hot French cinnamon to one five-and-twentieth only of the proportion contained in cloves. Hence it follows, that in these spices the degree of pungency of taste is dependent, not on the quantity of the volatile oil, but on its quality.

§ 89. **Heating Effect of Spices.**—In the first instance, it was, perhaps, only the pungent taste of the aromatic oils to which the heating effect of spices was ascribed; but the excitement and palpitation produced by their use, show that they accelerate the circulation. Not only, moreover, are the palate and stomach heated by direct irritation, but the cheeks also become tinged with a rosy glow under their influence.

These spices, by irritating the digestive glands, are also capable of promoting, to a certain degree, the solution of the aliments. Hence, the blood is not only provided with a heating oil, but also with an abundant supply of restorative substances; the nutrition is increased, as well as the formation of semen; the sexual impulse is excited, and especially by vanilla, of which the most essential constituent is volatile oil.

But sleep also is prevented, and the passions are aroused. All nutriments causing sleeplessness irritate the brain, and accelerate the movements of thought. It is, therefore, not a mere fiction, that mustard for the moment quickens the action of the memory; just like the movement of the muscles, memory is an action of the brain; it is capable of being called into exercise like every other manifestation of bodily power. But the action, as an attribute of matter, is confounded with the instrument itself, if we say that mustard produces a good memory. It is true the instrument cannot exist without matter; moreover, it is not the bulk of the substance, but the celerity and force of its motion, which is to be considered the essence of increased action. The motion ceases with the matter which excites it. When, therefore, the volatile oil has disappeared from the blood, the excitement produced in the brain is over likewise; the mustard cannot, therefore, be an instrument of the memory. I repeat it—memory is a form in which the action of the brain manifests itself. But to call the brain an instrument of memory would lead to a greater confusion of terms, than if we were to denominate the muscle the instrument of speed. The brain thinks just as the muscle moves; sensation and will, recollection and judgment, are different forms of thinking, just as stretching and shrugging, trilling and grasping, are different forms of motion.

The spices cannot be called restoratives, as their most essential substance does not convey to the blood an essential constituent; they are stimulants, and whatever stimulates renders over-excitement possible. An excess of stimulants, in the strictest sense, is therefore much more dangerous than a superabundance of nutriments. Sugar and common salt, butter and cheese, oil and vinegar, are far superior to the spices with regard to the service they afford to the body. When we consider the restless passion, the choler and insidious jealousy of those inhabitants of the tropics who take so great an abundance of spices with their food, we find it impossible to forgive the cruelty with which the Europeans of a former day sought to enrich their own part of the world with pepper and cinnamon, with cloves and nutmeg. Had they never possessed any of these spices, the people of Europe would have one superfluous, and often obnoxious, addition to their food the less; and the Spaniards, Portuguese, and Dutch would be able to erase a bloody page of their history.

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BOOK THE THIRD.

OF DIET.

§ 90. **Conditions and Definition of Diet.**—Real equality is shown in difference. We all are equal, only because even the slightest difference of circumstance produces a difference in the composition and functions of our bodies; another mode of life, another kind of food, another climate and soil, create a different blood and brain. And, indeed, when from the icy north up to the pure glowing sky of the tropics so rich in flowers, we pursue the manifold gradations which act upon man by the boldness of contrast, as well as by the abundance of varying transitions,—heat and cold,—mountain and valley,—sea and land,—forest and steppes,—animals and plants,—we are no longer astonished that many refuse to recognize, in the changeful and multiform human species, the children of one ancestor, seeing that form and colour, as well as mind and morals, multiply distinctions in so prodigal an abundance as to render the very conception difficult.

Whatever, in their numberless shades of form and composition, the earth and the water produce, exercises its influence upon the food of man. I no longer fear to give offence by designating food itself as one of the most important sources of differences in our species;—so much the stronger emphasis, however, must I give to the assertion that no influence exists, as an isolated one, in the history of our eternally progressing life.

Goethe, with reference to the important axiom of Haman, that everything isolated is objectionable, says, in a manner at once so true and consolatory in all the completeness of human intelligence and expression—"In every communication of thought, if not a poetical one, there exists one great difficulty; for the word must detach itself, must become isolated, in order to say or to signify something. By speaking, man necessarily for the moment becomes one-sided; there exists no communication, no doctrine without separation." On the ground of this necessity, it is to be explained why I have left in the back-ground the equally powerful influences of the air and the soil; of Nature as it surrounds us in the solitary forest, in the undulating mountain-region, in the wearisome monotony of vast plains, or in the awe-inspiring boundlessness of the tossing sea; why I have omitted to mention the intimate relation between plants and animals, the effect of the intercourse of man with man—now elevating, now degrading, often the source of the highest pleasures, but often, also, of the keenest wounds; why I have not specified the power of oral instinction, the magic of song: in order that I might speak with a greater emphasis of the far-reaching influence of food. Under the united influence of all these agencies, man becomes of necessity the being he is, comprehending the external world in just so many various aspects as the modes in which the latter acts upon him.

I have treated one part only of this series of food; but certainly not with the intention to remove a single link from the chain. The sea bordering the earth, and the earth the sea, both affect the condition of plants and animals; and these, again, occasion infinite diversities in the aliments of man according to the climate. The effects produced by food upon man determine the commerce and the character of the people, as well as the individual. But commerce again alters man, man the food, and food the fields; everywhere action and reaction.

And to this reaction, the power of which is the surest and most concise expression of the heaven-storming reason of the race of Prometheus, man owes the pliability, so tenacious and yet so flexible, by which he becomes indigenous in every climate of the vast domain of nature. If he approaches the north pole he contents himself with fish, while in the tropics he enjoys the fragrant fruit in addition to savoury game; and if in the plains of North America, the huntsman lives on the flesh of the buffalo alone; while the New Hollanders, possessing on their vast island no edible fruit, not even the size of a cherry, take animal food exclusively; in the tropics, where meat taken in abundance is injurious to health, a vegetable diet prevails, to which, indeed, the inhabitants of Pegu and Malabar, from superstitious motives, restrict themselves.

Our blood is intermediate in its properties between that of the carnivorous and the herbivorous animals; but it is not in the blood that the difference begins, in the first instance, which distinguishes us from the animals that live on an exclusive diet. In our digestive organs themselves, a compromise has already been effected; and those differences present themselves which are so sharply marked in the formation of these organs in the animals feeding exclusively on animal or vegetable food. If the herbivorous animal is enabled, by numerous and variously-formed teeth, to gnaw and grind, and by a long digestive canal and large salivary glands to digest substances which could not be sufficiently comminuted by the less-developed and sharper teeth of the beast of prey, nor dissolved by their smaller salivary glands and shorter intestinal canal; in man we observe, in the structure of the teeth and of the jawbone, of the stomach and of the intestinal canal, of the salivary glands and the muscles of mastication, a proportion intermediate between the two.

Man, therefore, is able to digest both vegetable and animal food; and as there exist vegetable as well as animal aliments in which all three groups of the simple alimentary principles are to be found,—as both bread and meat are able to convey to the blood its requisite elements, the native of Pegu gets accustomed to an exclusive vegetable diet, just as many North Americans live on animal food, and the Greenlanders almost entirely on fish.

Where both these products of nature—the gifts of the field and the gifts of the wood—exist in abundance, the taste selects from both sections some important representatives of nutriment; and if we denominate cattle and swine the domestic animals of man, corn and leguminous plants ought, with equal justice, to be designated his domestic fruits.

The more civilized that nations are, the more perfectly is the cultivation of domestic animals and fruits developed among them. Where agriculture as well as the breeding of cattle flourishes,—or, to speak more correctly, where a thriving stock increases the fertility of the fields, and a productive agriculture the opulence of the stables,—man takes for his nourishment meat and bread, milk and fruits. While digesting both with ease, the composition of his blood conforms to the digestion, just as digestion depends upon the structure of its organs; and if in man the digestion and formation of blood corresponds with his mixed food from plants and animals, will not a nutrition afforded by this mixed diet, just as it produces muscles and bones peculiar to man, develop also the brain, which, as really human, thinks and feels?

Equally remote from the savage hunting-tribes, kindred with that of beasts of prey; and the vegetable-eating Hindoos, with their greater mental indolence—not digesting in order to live, but living almost in order to digest—stands the cultivated European who digests his mixed diet with ease, and from whose blood is evolved a brain, the action of which we admire in those forms where human beauty and wisdom are embodied.

This circulating mutual action, which on all sides unites man with nature, is continually recurring; the difference produced by the degrees of this mutual action causes the peculiarity of the individual. After a brief description of the change of matter in the tissues, as it generally takes place in the human species, I passed in the second book to the description, in general outlines, of the action of the several aliments. As sex and age, position and mode of life, habit and climate, exert various influences, we know but one-half of the science of food, so long as our acquaintance is limited to the metamorphosis of tissue in the species, and to the general action only of the aliment. The remaining half consists in describing the manner in which the tissue-change, as modified in the individual, determines the selection of the aliments. This selection constitutes diet; and hence there remains for me in this book the task of determining the diet in the principal circumstances of individual life.

§ 91. **Breakfast, Dinner, and Supper.**—Although during sleep the metamorphosis of tissue is less rapid, yet the eight or ten hours which commonly elapse between supper and breakfast are sufficient to produce all those phenomena of sanguineous impoverishment comprised under the name of hunger. Hence, the meal breaking this state of fasting is called breakfast.

To the breakfast succeed the anxieties and labours of the day. Bread, therefore, or bread and butter in the morning is a very proper food, as it is digested with sufficient ease, and yet so slowly as not too suddenly to overload the blood and brain with alimentary principles. Tea or coffee suitably prepare for the attention and exercise of judgment, more or less required by the labour of all classes. And from the consideration that tea more especially promotes the combination and the development of thought, while coffee excites the imagination likewise, a rational explanation is obtained for the fact, that in some countries, as for instance in Holland, those classes of society whose labour is chiefly that of the intellect take tea for their breakfast, while those which employ both judgment and imagination take coffee.

§ 92. **Combination of Meat with Vegetables.**—Soup, vegetables, and meat, are the regular constituents of a European citizen's dinner. In the second book I have explained how the daily taking of soup, together with the meat, is necessitated by the general custom of preparing soup from the same meat which is eaten when boiled. In the same section I showed the combination of meat with vegetables or edible roots to be a custom founded upon reason. Meat furnishes what is wanting in vegetables, and the vegetables dilute what meat contains in too great an abundance.

It is therefore an unfortunate custom, or a still more unfortunate necessity, that by so many poor families potatoes exclusively should be eaten for dinner. When circumstances render it impossible to eat any meat with vegetables, the dinner ought to consist as often as practicable of leguminous seeds, the best of soups being from peas, beans, or lentils. Hence it follows again, that the distress of the poor might be essentially alleviated by the cultivation of the leguminous plants on so many acres of soil, where now potatoes grow, or perish by a destructive disease.

In those families, however, which have meat on their table some days of the week at least, the meat ought on those days to be dished up together with potatoes or vegetables, while on the other days the nutritious soups of peas, beans, or lentils should be used. Such an alternation ought to be laid down as a general rule; for however correct the taste of certain housewives may be in the selection of viands, it happens very often in the more opulent households of the middle classes that the meals are very improperly composed. How often does it occur that a meagre soup is followed by nothing but fish and potatoes! Or, how often is some kind of soup together with a farinaceous dish eaten without any addition of meat! Or a soup from some of the leguminous seeds is taken, and leguminous seeds or farinaceous dishes follow.

Whenever possible, meat ought not to be absent from the dinner table; or if the less readily digestible and less nutritious fish is even substituted, an easily digestible and substantial broth, or a nutritious soup of peas or lentils, ought to compensate for the defect. But if beans and farinaceous dishes, or soups of the leguminous seeds, constitute the whole meal, these most nutritious aliments will by their difficulty of digestion oppress the stomach, overload the blood, heat the head, and render it less fit for the ensuing work.

Pea-soup, therefore, with fish and potatoes, or fish followed by farinaceous dishes, or meat and vegetables, or broth, leguminous seeds and potatoes, or roast meat and salad, are suitable combinations foı a good meal. In short, the more easily digestible albuminous substances ought always to predominate; and when aliments which are more difficult of digestion form the chief constituent of a meal—when peas, beans, or farinaceous dishes are taken—then soups containing vegetables or fruit ought at least to be added, in order to promote digestion by their admixture of acids or salts.

But not only the right representation and combination of alimentary principles are to be considered in our meals. Whatever impels our body to a new activity is a stimulant; and hence, in a wider sense, not only are the heating spices, but solid and liquid food in general, to be regarded as stimulants. But it is characteristic of a stimulant that its effect ceases when its use is repeated at too frequent intervals; and the slighter the irritation, the more readily will its effect become blunted, if the regularity of its influence render the peculiar effect less perceptible; a diminished susceptibility to the irritation, in consequence of repeated use, establishes the habit; while, with many kinds of solid and liquid food—for instance, with bread, meat, potatoes, water, milk—our insensibility to the stimulus does not attain a higher degree than that of becoming accustomed to it; and while even stronger stimulants, like tea and coffee, beer and wine, are overcome by habit, with other aliments the insensibility overpowers the habit up to point of disgust.

While soup and meat, if taken day after day in the same form, at length become repugnant, it is equally impossible to eat every day the same kind of vegetables, the same farinaceous seeds; if carrots or sourkrout have to be partaken of even for two or three days in succession, the housewife may expect to meet with dissatisfied faces. This does not proceed perhaps from any bad state of the organs of taste, but taste is a very appropriate index of the irritation which the brain and the nerves receive from the blood. We know accurately that meat taken in abundance conveys more fibrine to the blood, and the starchy aliments more sugar; and that the volatile oils of the superior kinds of fruit and of spices, the organic acids and the several combinations of the different salts of the vegetables, pass into the mother-juice of the tissues. And if in animals the monotonous manifestations of strength correspond with their uniform food; if even in plants the want of sensation harmonizes with the simple composition of their not very numerous alimentary principles; must not the strictest logical sequence of cause and effect trace the agitated life of man, with his actions and passions, and all the numberless shades of sensation and thought, in great part to his variety of solid and liquid food and condiments? That there exists individualism in character, becomes possible only through the co-operation of the various aliments, together with the numberless moral and sensible influences which the surrounding material world exercises upon him.

And as the uniformity of the stimulant, even if repeated at longer intervals, is prejudicial to its effect, a regular arrangement of dishes, repeated certain days every week, is a custom not to be commended. If a stiff regularity only too clearly betrays a commonplace narrowness of mind, such a regular repetition becomes a source of petty formalism; insensibly, but all the more dangerously, repressing the free movements of the mind. Whoever has watched himself with attention will often enough have experienced how the refreshing and stimulating effect of a walk is evidently lost if taken for a long time daily at the same hour. It is the same with uniformity in viands; and while the ancient physicians used actually to assert it to be useful sometimes to throw the body out of order, in accordance with this doctrine it is perfectly true, that an inflexible regularity of life is by no means compatible with a genial freedom.

Not seldom do we hear the opinion advanced, that drinking during a meal is an obnoxious habit, but quite wrongfully; for the gastric juice may be diluted with a considerable quantity of water without losing its dissolving power in the slightest degree. Only a superabundance of water would diminish or arrest the peculiar action of the matters contained in the digestive fluids.

Large draughts of water, therefore, would be the most injurious with aliments difficult of digestion, like the fats; and hence the drinking of too much water after fat pork, for instance, is properly avoided; but, in countries where soup does not constitute a regular part of the meal, drinking water is positively to be recommended.

Beer and wine at dinner are also hurtful only if taken in excess; for in the latter case, the alcohol coagulates the albuminous substances not only of the food, but also of the digestive fluids, and thus disturbs digestion. If taken in a moderate quantity, these beverages are calculated to cause the meal to hold out longer; for the fact that we are not so soon hungry again after a meal with wine, than if we have taken only water with it, is to be accounted for by the slower combustion of the constituents of our body, inasmuch as the alcohol we have imbibed takes possession of the inhaled oxygen. Hence, wine with a meal is extremely useful when a long journey or work in hand renders it impossible to take food again at the usual time; so much the more so, as such detention from food itself usually causes an acceleration of the metamorphosis of the tissues, which beer and wine efficiently obviate.

The general preference of warm food at dinner is based on rational grounds; for a low temperature coagulates gelatine, and the fats coagulate, which are much more readily digested in a liquid state. But when the food is much cooler than the liquids of the stomach and intestines—that is to say, much lower than 98° Fah.—it subtracts from the latter a part of their warmth, and the colder combination effects the solution less readily. Ice, therefore, as well as very cold water, are injurious, particularly if the nutriments contain a large proportion of fat or gelatine. As great changes of temperature in our body in general are not easily endured, a sudden transition from warm food to cold, or *vice versa*, is injurious. By the sudden refrigeration of the heated cavity of the mouth, the enamel of the teeth is said sometimes to have actually cracked.

From the different hour at which the principal meal is taken by different individuals and classes, it sufficiently follows that no absolute rule can be given for this. This time is of little consequence to the classes having an occupation chiefly mental, and of none to those who do not work at all, provided, at least, they do not so utterly subvert the natural order of life, that night becomes day and day night. Those classes, however, which are engaged in fatiguing, bodily exercise, expend during the first six hours of the day so great a quantity of material, that almost everywhere they observe the custom of taking at noon, or at least not much later, their largest portion of restoratives.

§ 93. **Suppers.**—The German custom of taking supper two or three hours, or even longer, before going to bed, has this great advantage, that digestion is almost at an end before going to sleep; for digestion disturbs sleep, and sleep digestion. Hence, supper should consist as much as possible of easily digestible aliments, as soups, salad with little meat, and not of fish or leguminous seeds. It is only when supper is taken very early that the less digestible bread, or still better bread-and-butter, and meat, are proper food. When tea is taken in addition, those who are accustomed to perform close mental labour after supper are agreeably excited. Intemperance is, most of all, to be avoided in the evening; for, apart from the sleep being disturbed by digestion as well as by hunger, an overloaded state of the blood is less easily adjusted during the night. In the night less carbonic acid is exhaled, and the tissue-change in general retracted. Hence, an overladen state of the tissues, and especially of the brain, is very often manifested in the night by heavy dreams and nightmare, and in the morning by headache and a general state of ill-humour.

§ 94. **Diet of Childhood.**—In the form of a general proposition, and with application to special cases, I have repeatedly insisted upon the principle that the amount of restoratives needed by the system depends upon the extent of the expenditure. An abundant supply, accompanied by considerable expenditure, occasions an active metamorphosis of tissues.

Although the differences in man, as modified by age and sex, generally confirm this proposition, so that in a healthy man the activity of the tissue-change may be estimated by the quantity of the outgoings, still it is precisely here that we find at the first glance the most important exceptions. In the adult the weight of the whole body remains from day to day the same, allowance being made for the augmentation or diminution most recently produced either on the one hand by a meal, or on the other by excretions of different kinds; for here, in general, the restoratives exactly repair the loss of the excretitious parts.

Not so with the child: for that the infant grows to a boy, the boy to a youth, is entirely and solely effected by the receipt surpassing the expenditure. The balance is not even in the exchange of the body. We have not to deal with a simple tissue change. Growth consists in nothing else but in the proportion in which the formation of tissue exceeds the products of regressive transformation. The superior activity, however, of nutrition over excretion is the cause only of growth. The assimilation of the body in a greater proportion than it expends, is the condition without which it cannot grow. Strictly speaking, this greater appropriation of alimentary principles is growth itself. But its cause has to be more profoundly sought. The blood and the tissues of the infant are of a different composition from those of the adult. When treating of animal food, I mentioned that the muscles of young animals contain a greater proportion of albumen, but less of fibrine, than those of the full-grown. The real skin, in the adult consisting of fibres yielding gelatine, is formed in the infant of an albuminous substance which, however, is not entirely absent from the skin of the adult. The bones of the infant yield gelatine of cartilages or "chondrogen;" and the organic basis is by degrees only transformed into the tissue yielding gelatine of bones, or "collagen." Thus while in youth the solid parts contain a greater proportion of water, but less in weight of the formative substance deposited by the mother-juice, the tissues of the adult are, on the contrary, remarkable for their abundance of solid substance. As these solid substances are mostly heavier than water, their augmentation during the period of growth explains the increase of the body in weight.

But if the body of the child has another composition than that of the youth, we must not be satisfied with the fact that the quantity by which the receipts surpass the expenditure effects the growth. Tissues of a different composition likewise possess a different kind of attraction for the matters conveying the nutriment to the blood.

The muscles of the child attract fibrine from the blood, and their albuminous substances decompose into kreatine and urea; and the important consequence of their composition differing from the muscles of the adult is, that the fibrine attracted surpasses in quantity the products of decomposition taken from them by the retransformative process. The same change takes place with the skin, as its albuminous substance is decomposed and lost with the urine and the exhaled air, while with a superior attractive power it forms from the blood and assimilates the organic matter of its gelatinous fibres. But the remark is chiefly applicable to the bones; for just as these, more than any other tissue, cause the increase in weight of the whole body, so do they attract, in return for the wasting matter (known by yielding, when boiled, gelatine of cartilage instead of bone-gelatine), such an abundance of the true bone-constituents, that in a very short time their composition entirely changes. While gelatine of cartilage possesses a strong affinity to common salt; the tissue yielding bone-gelatine has the greatest tendency to combine with phosphate and carbonate of lime. With the growing preponderance, therefore, of the bone-gelatine over the gelatine of cartilage, the lime-salts are continually increasing, and that during the whole life. The bones readily collect the lime-salts and the fluoride of calcium from the blood, a function shared in equal degree by the teeth only.

This strong attractive power, peculiar to the infant and child, is more than the condition,—it is the real cause of its growth. It explains how it happens that the nutrition is in proportion to the excretions; a circumstance which I have before shown to be the condition of growth and increase of weight.

In the infant, therefore, change of matter only follows the same law observed in the adult. In both, the attractive power of the tissues towards the constituents of the blood induces nutrition. If, from the peculiarity of their composition, the tissues attract and detain a greater proportion of the blood than is lost by excretion; the blood, in order to maintain its composition, has to receive a larger quantity of the alimentary principle than would have been necessary if the activity of the nutrition had been simply equal to that of the excretion.

The direct expenditure of the blood upon the tissues, therefore, determines its supply; only the different composition confers upon the freshly-formed constituents of the tissues a greater constancy, and for this reason the body appropriates more than it eliminates.

This explains why children take proportionally more food, and especially why they take it oftener than adults, although the latter discharge a greater quantity of carbonic acid than the former; and thus the regularity of the phenomena establishes the law—as it can be proved that the exception was only apparent. A law has its full validity only when the exception which withstands its authority, merges in the law as soon as the conditions of the seeming anomaly have been more exactly ascertained.

Scientifically, therefore, we come to the conclusion that the supply is regulated by the expenditure, and that in the infant, as in the adult, the exchange of the constituents of the blood is rightly denominated the change of matter. Practically, it results that the child's frequently recurring desire for food does not arise from mere ennui or restlessness, but from processes in the interior of the body; and hence the rule that the infant should not be trained by the power of habit to a diminished and less frequently manifested desire for food, but that his instinct ought to be satisfied; as the general and natural expression of a law regulating the peculiar change of matter, which causes the inclinations of the child to differ from those of the adult.

It is, therefore, quite proper that at first the mother should give the breast to the nursling as often as it awakes. Gradually the child desires milk less frequently; and in the distribution of the meals for her child, the wakeful eye of the loving parent may trust to her own observation. On an average, the child, after being suckled, can wait three to four hours until the next meal. Very healthy and strong children frequently sleep even for six or seven hours together without being awakened by the want of food.

The child, after weaning, does not require any food at night; and the same rule holds good for boyhood. During healthy sleep the change of matter in children is moderate. This explains why even those whose want of food is generally so great, can easily wait from supper to breakfast without eating anything; while during the day the desire of food has to be frequently satisfied. It is a very wholesome custom to give to children a slight repast between breakfast and dinner, and another between dinner and supper,—nothing, indeed, tends better to accustom them early to temperate habits; for in order to thrive, they have to convey to the blood the same quantity of nutriment whether they take it at three or five times. In the latter case, the stomach is less gorged at any one time, digestion and the formation of blood go on with greater ease, and in the process of nutrition there is less danger that too great a quantity of nutriment should be conveyed to the tissues, which might have an injurious effect, especially upon the brain.

On the other hand, children are very materially injured by being gratified whenever their excitable palate asks for food or dainties; for as the formation of all secretions requires due time, just as the development of the ovum and semen, and the accumulation of milk, are bound to certain periods; so the digestive fluids, the saliva for instance, the gastric juice, the bile and pancreatic juice, are only secreted in a sufficient quantity for the usual meals. We must, therefore, allow the digestive glands the needful time to prepare and collect them between one meal and another. If not, the requisite power of digestive action is deficient just at the time when the most nutritious aliments, soup and meat, are taken. At table, if children complain of want of appetite, and if accordingly they do not eat, the blood becomes deficient in the best alimentary principles; if compelled to eat, on the other hand, imperfect digestion makes them languid and thin.

§ 95. **Milk as Food for Children.**—That milk is the most appropriate food for children is so generally recognized, that science has nothing to do but to confirm and interpret the fact.

Combining in a due proportion solid and liquid food, milk contains not only in the caseine an albuminous substance, which is transformed into albumen and fibrine, afterwards into gelatinous horny and elastic fibre; it has also in its peculiar sugar one of the most easily digestible constituents of fat, and in butter the ready-formed fats which assist in forming the soft cushion of round limbs and full cheeks in children.

But it is the phosphate of lime so abundantly contained in milk which particularly constitutes this the most fitting nutriment of the babe. In milk, more than in any other food, the conditions are furnished for the transmutation of the cartilages of the infant into bones. The phosphate of lime, so constantly associated with the caseine, is easily dissolved by the lactic acid, into which the sugar of the milk has been transformed by the bile; and thus the dissolved lime-salt passes from the digestive canal through the blood into the bones. The phosphate of potash performs the same office for the growing muscles.

In the milk of animals we find the same constituents as in human milk. Can, therefore, the latter be substituted for the former?

A direct comparison of the milk of woman with that of the Mammalia, decides the question in the negative; that of woman contains a much smaller proportion of caseine, a smaller proportion of butter and of salts, but a greater quantity of sugar of milk and of water than is found in the milk of cows.

But whoever has attentively followed me in the description I have given of the change of matter, will not see anything fortuitous in this difference of composition. Here, as in many other cases, the manifold links are wanting, which enable us step by step to prove the differences of power to be nothing but differences of matter: now we have a better knowledge of the matter than of the force, and now the reverse. In a thousand instances, however, the power has been so distinctly proved to be a necessary quality of the matter, that, like all other qualities, it is an inseparable characteristic of the body, conditioned by the peculiar composition of its matter.

It is no empty prejudice to state, nay it is a real belief in the general prevalence of a demonstrated natural law, that the nature of the mother is communicated by the milk to the child. And there is no thought more natural than the belief, that on the breast of its mother the infant may imbibe, together with the milk, her nobleness of mind, with the love which devotes that food to the most sacred purpose, and fastens still more strongly around the feeble child and the tender mother the ties of their endeared relationship.

There are certain differences, though slight, between the milk of one woman and that of another; and as in successive months after confinement the milk alters in composition, the difference is so much the greater, as the children of the mother and those of the wet-nurse differ from each other in age. Since, in any case, the milk of the wet-nurse will be dissimilar to that of the mother, the closest possible conformity ought to be secured, where a wet-nurse is sought, between the age of the two children. Under any circumstances, however, the milk of a wet-nurse more resembles that of the mother than cows' milk; and therefore the milk of a wet-nurse is to be preferred to bottle-feeding. It is true that in large towns healthy wet-nurses are scarce; and still rarer, perhaps, that devoted love which nourishes a stranger's child as carefully as is desirable; for the effort is, indeed, not slight, by which a woman has to restrain her own will and inclinations to such a degree, as to prevent indisposition of body or any bewildering passion from becoming hurtful to the babe; the easily excitable nature of the woman is often influenced to the great disadvantage of the child. Out of the manifold inconveniences arising from these circumstances, mixed food produces a more frequent uneasiness of body, than where uniformity of food is observed.

Hence, in many cases of difficulty, bottle-feeding will be preferable to the employment of a wet-nurse. By diluting cows' milk with one-third of water, and adding to five-and-twenty parts of milk about one part of sugar, a sufficient similarity with the milk of the mother is obtained. If asses' milk is to be got, which is seldom the case on account of its high price, the dilution of the whole, and the increase of the proportionate amount of sugar, is very simply effected by mixing about two parts of asses' milk, which is remarkable for its abundance of water and sugar, with one part of cows' milk. As the milk in the first days after confinement contains more solid constituents than it does from about the fourth day afterwards, the cows' milk should for the first days be diluted with a smaller proportion of water; but after the fourth day more than one-third of water is to be added to good cows' milk—a proportion which must gradually be diminished again, as the milk of the mother, after having become considerably thinner on the fourth or fifth day, increases again by degrees in the amount it contains of caseine and salts. Like all liquids of the body, the milk in the mother's breast has a temperature of 98° Fah. At this temperature all aliments are most easily transformed by the digestive fluids. In bottle-feeding, therefore, the mixture employed ought always to be warmed as nearly as possible to 98°.

A long time before the period for weaning arrives, and earlier if the mother has not sufficient milk, more solid food may be gradually given. From rusks, fine wheaten flour, potato-starch, or arrowroot, first combined with water, milk, and sugar, and afterwards with broth of different kinds, a spoon-meat is prepared, usually much relished by infants. While in rusks and wheaten flour the albuminous substances themselves are present, in the mixture prepared of potato-starch or arrowroot these are only contained in the milk, or in the juice of meat (for it is to be taken into consideration that arrowroot differs from potato-starch only in being composed of smaller granules, and by its forming with boiling water a thinner paste); arrowroot, in fact, is nothing but starch; but starch represents only the group of organic alimentary principles destitute of nitrogen, and among these the constituents of fat; now as the constituents of fat alone are not able to maintain life, arrowroot boiled with water only, cannot restore and supply the various essential constituents of the blood. With a paste of arrowroot and water, children may be fed to death, but they cannot be nourished; and many a child has succumbed to this diet, an unhappy victim of the lamentable error that the highly-commended arrowroot was of itself a complete nutriment.

Even after weaning, soft mixtures of a good bread with milk and sugar, or with the juices of meat; also the more readily-digestible roots and vegetables, together with soups prepared from the meat of young animals, may be considered the best food. After the teeth are cut, meat and bread, in their simple form, may also be given. Aliments difficult of digestion, fat meat, heavy bread, rich pastry, unripe wheaten grains, leguminous seeds, and heating condiments, are carefully to be avoided for children; and of beverages, water, milk, and a light beer only deserve commendation.

§ 96. **Diet of Youth, Maturity, and Old Age.**—While the boy is growing into the youth, the composition of his blood and tissues more and more approaches that of the mature body. As the muscles acquire more fibrine, the skin and bones become richer in gelatinous substances; in the bones and teeth, the lime-salts increasingly predominate over the common salt; and the whole activity of the change of matter is altered.

As at other times, so during this period, the expenditure of the body furnishes the best means of estimating the extent of these changes. The proportion of carbonic acid excreted by the lungs, and that of urea voided by the kidneys, increases up to maturity, attaining its height at about the thirtieth year; but at about the fortieth year the activity of the tissue-change already begins to decrease, and the most important alterations gradually take place, of which those only of the tissues of the bones have been investigated with any degree of accuracy.

Of the solid parts it is known in general, that in old age the proportions of water and fat decrease. Hence, the tissues of the eye become drier, and the light is less refracted through the crystalline lens, which becomes poorer in water; hence, also, the shrivelled hands and the wrinkled brow. That the hair is altered in its material composition is proved by its gray colour, the venerable decoration of old age; but of the bones, we know that they become more and more brittle, because, in proportion to their organic basis, the quantity of salts astonishingly increases, and it is particularly the phosphate of lime which more and more predominates; for, although the salts on the whole increase so considerably, the carbonate of lime decreases relatively to the phosphate of lime; which latter, therefore, in a stricter sense, is so often denominated the bone-earth.

Nor is the organ of thought without its share in alterations so important. In advanced age, the proportionate amount of fat in the brain diminishes, while, unlike all other organs, its amount of water augments.

Is it, therefore, to be wondered at, if the excretions undergo essential alterations? or, should the tissues, exposed to the same influences as before, although themselves differently composed, yield equal quantities of the same products of decomposition? I repeat what I dwelt upon at the commencement of this book as the reason assigned for the selection of aliments. In difference only lies the equality of men; only by the variety of circumstances, affecting both the matter and the force of our organs, can we be different; we are all equally dependent on air and soil, on men and animals, on plants and minerals; we could not have been primitively all equal, could we maintain equality under the different influences to which we are exposed: it is upon the difference of circumstances that our own differences are based.

Age is an essential element worthy of notice in this difference. The tissues have now another composition; in old age less carbonic acid is breathed out, less urea formed. The drier tissues, containing a greater proportion of salts, undergo their normal transformations more slowly; the diminished decomposition proves a diminished activity; that renewal of matter, which is so abundantly induced by the decomposing action of oxygen, is gradually weakened; a smaller proportion is decomposed, and a still smaller portion formed.

Thus the susceptibility to all sensible and mental impressions gradually becomes enfeebled; that which formerly would have made a powerful impression, scarcely now leaves any trace in the form of memory. But a rich life lies behind the old man. Though now receiving less, the crown of a maturer experience adorns him. Ripe fruit which he has collected for himself and others, gladden the last years of his life, and increase the cordial and elevating sense of gratitude, with which we render homage to the venerableness of old age. "In the late evening of a much agitated life," Alexander von Humboldt, whose very name illustrates the idea, lays before the world his Cosmos, "the idea of which, for almost half a century, had been floating in uncertain outlines before his mind;" and with it he enkindles the spirit of everyone, whose view is not narrowed by those barriers, which only too often separate all sublime enthusiasm regarding the universal from the arid, and relatively sterile, assiduity which stolidly confines itself to mere details.

Not in every case, and not for very long together, can such a noble picture of man be exhibited. With the diminishing vigour of the change of matter, the torch of life gradually sinks. More and more slowly the matter moves from the digestive organs to the blood, from the blood to the brain and muscles. At length these activities wholly cease; for all that lives, bears in itself the germ of death. Those laws of gravitation which alter at every stage of life in a necessary succession, lead through growth to perfection, and from the blooming prime by a regressive transformation to decay. Not only do fat and water disappear, the bones also lose in circumference. While the latter become richer in lime, harder and more brittle, the wrinkling skin shrivels up, the cartilages ossify, and the watery brain loses more and more of its essential fat. Mentally, as the retrograde course continues in unbroken progress even to death, a kind of revolution is usually completed. The memory becomes dull, even for youthful recollections; and to the other infirmities of old age, a hebetation of the senses finally supervenes, which distorts the judgment and destroys the memory; the old man who was before so venerable in his unbroken strength, bringing out the results of the experience of his former life, gradually becomes the image of a helpless child. Dissolution then becomes a blessing, and with respectful awe we drop the veil over that last proof of feebleness from which no mortal being can escape.

Matter, however, is immortal. Into the grave we let fall the noblest seed, with the certain knowledge that the transiency of one form "which has been bleeched by the abundance of years," will yield to flowering and fragrant plants of the fields, to rise again after numberless transformations in fresh and youthful vigour, and still co-operate in the task, in which the spirit of all human works continues to live amongst us, visible to our senses. For the spirit is eternal, as manifesting itself in eternal matter; while the terrestrial eternally changes, the earth and its inhabitants are eternally renewed.

§ 97. **Requirements of Youth and Age.**—As growth continues during the time of youth, so the young not only require to satisfy their appetite oftener than adults, but need also a more nutritious diet. The attractive power towards the alimentary principles is greater, and the blood yields more to the tissues in spite of the excretions, subtracting altogether a smaller proportion from the body than in mature age. If the adult, therefore, requires meat and bread or leguminous seeds to keep up the necessary strength for the tissue change, this necessity is so much more peremptory with youth.

At the time of transition from boyhood to youth, care must be taken not to carry the nutritious diet to excess; for it is essentially characteristic of healthy development, that precipitance leads only to an unhealthy precocity in instincts, thoughts, and actions. The formation of semen causes the sexual impulse. But the semen is remarkable for its amount of an albuminous principle; and hence an excessive animal diet precociously excites the sexual impulse. The luxurious mode of life of the higher classes in towns, is a main cause of those slender and pale figures of young men and girls, in whom a precocious instinct has driven the fresh roses from the cheeks, and the marrow of youth from the limbs. It is also true, that a too early reading of impassioned poetry, and of other books over-exciting to the imagination, also often creates a premature consciousness of the difference of sex. This maturity, hastened on before the development of the whole organism, first engenders those feelings in the boy, whose healthy nature ought proudly to break away from them to find in the woods and fields, schools and books, that which should arouse the mind to true and solid endeavours; at a later period, the young man becomes the victim of a passion, the only natural gratification of which is, in our social condition, reserved for a more mature age.

Granting him all adequate gratification, the growing youth should be provided with cooling aliments, fruits and vegetables, water and acidulated beverages; and if then his mind is sufficiently occupied, and he takes abundant exercise in the open air, the tissue-change will harmoniously promote the proportionate development of every part, and youth will enjoy the pleasures of youth.

In mature age a fixed diet is the least needful; the full-grown man discharges as much carbonic acid and water, urea and uric acid, with other excretitious matters, as he takes up of food and inhaled oxygen. His wants he can measure by his appetite; the latter recurs less frequently and is sooner satisfied than in youth. Every kind of excess, however, must be avoided, and this is infallibly secured by always leaving off before appetite has disappeared. Without this precaution excess is easily possible, because the limited size of our lungs, and the definite power of our movements, restrict the power of the change of matter. If man eats more than he excretes, the tissues become overloaded, which endangers their activity as much as the impoverishment of the blood and the consequent defective nutrition could do; fat is collected which the oxygen does not consume, and the albuminous substances, with the salts, assume a fixity which at once enfeebles the intellect and destroys the pleasure of thinking, while it diminishes both the strength of the muscles and the inclination for movement. Thus do gluttons gradually grow lazy, impatient of thought, anxious only for repose, and unfitted by their unwieldy frames to embody the moral and intellectual greatness which characterises noble-minded men.

Apart from the mode of life and the degree of temperature of the surrounding air, the influence of which latter I shall afterwards describe more in detail, the peculiar constitution of the individual deserves a special consideration. It is true that here the grades of difference are as numerous as the population of the globe. The natural disposition, with a certain tendency to firmness in the functions of the brain, gradually produced by the school of life, form the character. The greater this firmness is, and the higher the courage with which it is displayed, the more naturally do we call the man a "character" in the good sense of the word; but, inasmuch as every individual holds a necessarily defined position in his relations to the external world, every one has more or less of distinctive character. On account of the innumerable degrees of transition, however, this rule can only be applied to the extreme representatives of one class or another.

The more vivacious the disposition, the more easily the man is excited by stimulants; the greater, also, will be the tissue-change. Generally speaking, such individuals will need food more frequently than those of a less excitable nature. With individuals of this habit, too nutritious or exciting food is to be avoided, because, as a stronger stimulant, it increases their nervous irritability. Vehement, passionate natures become still more ardent from partaking of game, heavy bread, leguminous seeds, or any considerable quantity of beer, wine or spirits, coffee or tea. By these more fermenting aliments the circulation is accelerated; the tissues, especially the brain, are overladen with blood; and the skin, which in such persons is very easily filled with blood, turns red, especially in the cheeks. This heat is moderated by cooling aliments and beverages. Fruit and vegetables, therefore, with lemonade and similar drinks, are more advantageous for irritable constitutions than spirituous and aromatic beverages.

The latter are more appropriate to persons whose activity of the brain is disproportionately great; while their weak digestive organs, their slow formation of blood and nutrition, occasion a disposition to melancholy. Such persons require a stimulating diet. On account of their slow digestion, they have to select such nutritious aliments as are easily digestible; such, for instance, as the flesh of fowls and pigeons, veal, mutton and veal-broth, in conjunction with a small quantity of light, well-baked bread, or of vegetables. As heating spices, wines taken in moderate quantity, as well as strong tea and coffee, accelerate digestion, and with this indirectly the tissue-change; they produce a greater uniformity in the functions of the different organs, and thus exercise a beneficial influence upon disposition and character.

And, finally, where a slow tissue-change characterises also the main parts of the nervous system, the brain, and spinal cord,—where slight irritability is united with flabby muscles, a pale, flaccid, puffy skin, an inert digestion, and a deficient formation of blood, as in phlegmatic persons,—a nutritious animal diet is to be combined with strong spices, strong beer, and wine. Vegetable aliments, especially roots containing much starch and sugar, must be avoided by all such; and for this reason, that in such persons there commonly exists already an excessive disposition to deposit fat, which, being itself the consequence of a less vigorous respiration, becomes a check to the tissue-change; the large quantity of fat withdrawing from the other constituents of the blood the oxygen necessary to transformation.

With the last-named characteristics, those of old age are chiefly to be classed; for here, also, the enfeebled activity of the digestive organs is the salient fact. If the diminished activity of the tissue-change is manifested by a languid appetite, it is so much the more necessary for the aged man to choose the most easily-digestible food. Lean meat, venison, strong broths, young vegetables, and roots, as carrots, containing abundant sugar, deserve the preference; while stimulating condiments, coffee, tea, a good old wine, a strong bitter beer, taken in small quantities, serviceably promote digestion.

§ 98. **Diet of Woman.**—The general laws of the change of matter are fulfilled in the case of women through another circle of developments than in man; for at the moment when sexual maturity begins to manifest itself, that continual augmentation in the exhaled carbonic acid, which in the female, as in the other sex, lasts as long as the child is growing into the maiden, ceases. During the whole time that the procreative faculty peculiar to women exists, a uniformity is maintained, which yields to a slight increase only after the cessation of this faculty; and in old age, as in males, gradually declines. At every age, however, the quantity, not only of the exhaled carbonic acid, but also of the urea daily voided, is much smaller in the female than in the male sex.

While woman, therefore, is remarkable for a less active tissue-change, a slighter muscular power, and a calm, contemplative activity of the brain, which is less easily aroused to greater exertion of thought, she is also less subject to wild passion; self-control appears to be the necessary consequence of material conditions, although the whole position of woman in life, and particularly the relation of the mother to her child, combine to ingrain these mental peculiarities into the true feminine nature. The material basis of the female body is the best proof that neither an arbitrary conventionalism, nor the unutterable longings of the youth indulging in sweet hopes, have evoked the attention and the cheerful support which everywhere men have devoted to the fairer sex. Although, in many uncivilized tribes, the strength which women gain from endurance encourages the men to burden them with correspondingly heavy work; still the woman enjoys everywhere the assistance which she necessarily wants. And when, with a higher civilization, the consciousness of the dependence of woman increases, together with that of the dignity of motherhood, the superior power of man affords protection, his assistance becomes homage. The maiden's loveliness, added to the dignity of the wife and mother, helps to adorn the life of more rugged and ambitious man, her gentleness of manner producing that love of art which so often represents the wife in a noble ideal: this is the enjoyment which indemnifies the wife for great sacrifices; owing to a less direct contact with the rough storms of external life, she is able to cultivate a purer humanity, out of which the characteristic of womanhood is born.

The secluded life usually led by woman produces that perfect symmetry of nature—that fascinating serenity of manner, by which the matron is distinguished and adorned. But inasmuch as her life is less agitated, her manners more subdued, and her whole nature more accustomed to self-denial; so are the contrasts less marked between one woman and another. Their characteristics are less distinctive, and their peculiarities manifested in more delicate and minute distinctions—distinctions only to be accurately discriminated by the most acute observers. Even their features partake of this delicacy; and the painter finds it especially difficult to catch the more delicate peculiarities of expression in the female face, or infuse the characteristic expression into the less strongly-marked features. In woman only is found that charming harmony in which it is difficult to point out any salient part, because the equable and cultivated tone does not permit any particular point to be prominent. The least favourable aspect of this harmony lies in the greater monotony which distinguishes the sex from man. Of this peculiarity, the greater equability of the change of matter is at once the consequence and the cause. The variations in the quantity of the exhaled carbonic acid, so great in man, disappears almost entirely if we compare woman with woman. With the excretions, moreover, all the corporeal activities are moderated to a greater uniformity, as, on the other hand, the narrower sphere in which the life of the woman moves, reduces the change of matter also to a more equable course.

With this fact, the greater nervous irritability of the female sex in general is quite consistent, for the slighter vivacity of the change of matter produes a diminished demand for nutriment; but nutriment, as well as the mental impressions, belongs to the stimulants, in the wider sense of the word. And the more sparingly the stimulants are used, the stronger in proportion is their effect, and the more quickly also does that effect again cease. As the change of matter specifically stamps its impression upon all the functions of the body, so most women are easily excited, but soon regain their self-command; in man, on the contrary, the stronger impression usually produces more lasting effect.

§ 99. **Appetite of Women.**—From this description of the change of matter in the female sex, it follows that the restorative substances are required in a smaller quantity than in man. It accords with a general result of experience, that a less nutritious diet, or nutritious food in smaller quantities, suffices to satisfy the want of women; it is, therefore, no prudish or dainty affectation, but a natural abstemiousness, which leads girls and women to partake sparingly of food.

In pregnancy, however, when the mother has to form blood both for herself and her offspring, a greatly increased appetite is often observable. This should be satisfied with easily digestible and nutritious food, as the salutary development of the infant is as much promoted by an abundant conveyance of nutriment to the blood of the mother, as it is endangered by a contrary course, in which her health is impaired by difficulties in digestion or indifferent nutriment. In the first days after confinement, a less nutritious diet must be chosen in order to prevent inflammation, gradually passing on the fifth or sixth day from gruel to weak broth or beef-tea, and stronger food; during the following time of suckling, nutritious aliments and beverages are to be recommended. As the caseine of the milk can only be formed of albuminous alimentary principles, these especially must be taken in the form of meat, good bread, milk, eggs, and similar diet. The sugar of milk, on the other hand, is only formed from the constituents of fat, the butter of these, or of some other readily-formed fat; and hence those aliments also are of high value, in which the constituents of fat are most abundantly present. For this reason, bread and potatoes, chestnuts, and leguminous seeds, taken in an easily digestible form, are exceedingly advantageous to a nursing mother; and from the abundance of sugar contained in the human milk, it is to be explained why, in so many cases, those aliments which are rich in starch augment a scanty secretion of milk. In this respect the utility of chestnuts is well known; but it is a mistake to suppose that chestnuts supply the whole of the milk; for this, an abundant representation of the albuminous alimentary principles is required, not only on account of the caseine of the milk, but also because experience has shown that starch, with other substances of the same group, is transformed into sugar with special ease by the auxiliary influence of the albuminous matters. This influence is so great, that the quantity of the milk secreted corresponds with the proportion of albuminous substances which have been digested by the mother.

A scanty food, on the contrary, diminishes the milk in the breasts. Whoever has been unfortunate enough to be called in as medical man to starving infants too far gone to be saved, and whoever has witnessed with a feeling heart, or experienced himself, the intimate relation between mother and child, will readily admit that the most sacred duty of all obligations ought to be that of securing to the poor mother the food necessary for herself and her child.

If the suckling mother has, as a general rule, avoided all aliments which are difficult of digestion for her (as every indisposition of the mother may have an injurious influence upon the child), so in particular should she cautiously avoid all vinegar and acid fruits, which do great harm, probably, by dissolving the caseine of the milk-globules which includes butter. Thus much is certain, that vinegar, taken in considerable quantities, diminishes the amount of milk, besides rendering the diminished fluid less nutritious.

In cases where the mother cannot suckle, and a wet-nurse is preferred to artificial feeding, it must never be forgotten that the wet-nurse is to be maintained in a healthy state, and is not to be petted and spoiled. In opulent families, it is too often the practice to provide a stout and healthy wet-nurse, with the view of making her comfortable, with luxurious food and dainties to which she has not been accustomed. This injurious practice too often brings on difficulties of digestion, as a first cause of indisposition or actual disease in the wet-nurse; while the babe is a sufferer from the inconsiderate pampering and daintiness of the person who suckles it. Without giving more attention to this subject than it would seem to require, I would lay particular stress upon her being kept in all respects, in food and manner of living, as much as possible in the same condition as she has been formerly accustomed to, when in her usual state of health and in the possession of abundance of milk.

On account of the greater irritability peculiar to women, they commonly have a disinclination to strong condiments and exciting beverages. To coffee and tea only do they accustom themselves, and that to such a degree, that they do not suffer any injurious effect from them. Both beverages are much relished, especially by aged women. In general, however, neither tea, coffee, wine, nor any of the heating condiments are wholesome for the female sex; of these aliments, tea and coffee only ought to be taken, and that in great moderation, diluted with a large proportion of milk; this is most emphatically to be recommended at those seasons when girl or wife is especially reminded of her womanhood. To the girl, and to the expectant as well as the suckling mother, coffee, tea, wine, and spices, if taken in abundance, are directly injurious.

With respect to tea and coffee, special caution must be observed during pregnancy, inasmuch as animals have been known to fall into premature labour immediately after taking thein. As this principle is contained both in tea and coffee, these beverages ought to be taken in moderation only.

§ 100.—**Diet of the Artisan.**—An active change of matter increases the muscular power; but, on the other hand, the exertions of the muscles augment the activity of the excretions. He who digs the soil with the spade, or wields the hammer, who breaks-in horses, or wanders in the open field—not only perspires more, but also breathes out a greater quantity of carbonic acid, and voids more urea, than the man who by luxurious and indolent tranquillity encourages the fat of his body and an increase of the albuminous substances.

A real development of strength is inseparably bound up with an active change of matter. But change of matter consists of excretion and restitution; for he who exchanges, receives while he gives. The permanence of the substance does not contribute to the increase of activity. I have already several times expressly mentioned that, though the presence of matter is the condition of all activity, yet the rapid movement of this matter only intensifies the manifestation of power. The limbs, therefore, if kept at rest, relax; and in return, the whole advantage of exercise consists in the excretion of the muscles being augmented by their exertion, the nutrition of the tissue being increased by that augmented excretion, and the appetite being roused, correspondently with the necessity of forming new blood occasioned by the accelerated excretion and nutrition. The rapid change of matter increases the power of the organs, just as the exertion of the limbs promotes the change of matter, and the increase of muscul[illegible] power.

But to attain this, an abundant restitution is an indispensable condition. It is, therefore, equally consistent with economy as humanity for those who employ labourers on heavy work to satisfy the more frequently and strongly recurring appetite of their workmen; for it is only when the workman thrives that the work can prosper. Insufficient food causes feebleness and inertness; and the master who scantily feeds his workmen, loses more in the decreased strength of their arms, than the aliments would cost him which would raise at once the value of their achievements, and the dignity of their nature. Here other nations may look at the example of England. It is true that even there, thousands of operatives in the manufactories starve in hunger and filth, sending up a mighty and growing accusation into the palaces of the wealthy classes; but England, nevertheless, possesses a great number of workmen who owe to her nutritious beef the vigour of their limbs and the magnificent products of their industrious hands.

By every one engaged in heavy bodily labour, a nutritious diet is required; and as in a rapid change of matter the digestion participates in the activity of the other functions, the appropriate aliments here are meat with bread, containing a large proportion of gluten and leguminous seeds; while the preferable meat is beef, containing a good quantity of fibrine,—in a word, the most serviceable aliments here are those which are also the most difficult of digestion. And these more especially deserve preference, if circumstances or the kind of employment render it impossible immediately to satisfy the want of food recurring at short intervals; the aliments in this case are rendered more difficult of digestion, through their being more slowly transformed into the constituents of the blood and tissues, they also undergo less rapidly that decomposition which transmutes them into the excretitious substances. By this strong food the labourer is enabled to resist the calls of hunger for a longer period; and this—in spite of the obstinate denial of mock-philosophers who are deluded by their own luxurious life into a contrary belief—is the lurking enemy whose attacks continually irritate the anxious pater-familias among the poor. In these circumstances the leguminous seeds are an essential alleviation to sufferings arising from hunger.

Corporeal exertion increases not only the expenditure of carbonic acid and urea, the voidance of water as well as the excretion by the lungs and kidneys, but the expenditure by the skin and sudoriparous gland is also augmented. The loss of water, particularly, is increased by those actions which directly produce a more abundant evaporation from the mucous membrane of the tongue, throat, and lungs; as, for instance, by talking and reading, by singing and blowing. Hence, teachers and lecturers, singers and trumpeters, glass-blowers and public criers, are subject to extreme thirst; so also are all workmen who from their avocations are exposed to a high temperature, which stimulates the activity of the skin, and in a high degree augments the perspiration. This excites in glass-blowers the desire for drinking, and is the main cause of the often returning thirst in smiths and iron-melters, sugar-boilers and cooks, bakers, and gardeners working in hot-houses. On the contrary, thirst is at a *minimum* in fishermen and sailors, who ordinarily live in a moist atmosphere, into which a smaller quantity of water escapes from the human skin and lungs. That sailors are partial to brandy and other spirits, arises from another cause; for, on the one hand, through the alcohol, which demands the inhaled oxygen for its own consumption, the food of these labourers, which may be limited to a scanty meal, enables them to hold out for a longer time; and, on the other, the fat, which the alcohol assists to preserve, frequently protects and comforts the mariner in the rough weather to which he is exposed.

A good beer partakes in all the advantage of the alcoholic beverages, and at the same time usefully quenches the thirst by its more abundant amount of water. Hence, this beverage is particularly adapted to satisfy the frequent thirst caused by bodily exertion; it is, therefore, a laudable custom to refresh artisans, who have to work hard, in the morning and afternoon with a glass of ale; this beverage, by its proportionate amount of albumen, which is equal to that of fruit, supplies even a direct substitute for food.

§ 101. **Diet of the Artist and Literary Man.**—If the brain, like any other part of the human body, is subject to the processes of tissue-change, it is evident that a greater activity of this main organ of the nervous system will augment the products of decomposition. Thus all the sensations and passions which increase the mental action—as hope and joy, anger and ambition, suspended expectance and happy love—excite the instinct for food. By vigorous exertions of the will, active imagination, sustained thought, the change of matter is likewise accelerated. It is true, this does not prevent one sensation from being able, as it were, to neutralize another. How often do we observe that from joy or love, anger or suspense, a person cannot eat—or, in other words, the sensation of hunger is not perceived—while the intellectual power of the brain is over-exerted. But the desire for eating and drinking is only momentarily blunted; and after some time hunger and thirst re-assert their claims with a double force.

The far-spread error that mental activity does not increase the consumption of matter, originates in our repugnance to admit the fact, so strongly forced upon our observation, that the power is inseparable from the matter; for how many, even of those who have exclusively devoted themselves to the observation of nature, amuse themselves in vain speculations, about an essence of bodies, external to or hovering over them. And how few have a clear insight into the position which, since Spinosa, can no more be banished from science, that the total of all qualities makes the essence of a body. Only too often we may observe that in an unguarded moment intelligent men freely, and without prejudice, assert in some single instance the doctrine, that their mental actions are conditioned by the matter, which by the nutriment is conveyed to the brain. But as soon as this seeming casualty is raised to a general law, they are terrified by their own significant presentiments, and fly from the clearness of conviction, in which only they could find satisfaction. This vague separation, however, of matter from power, which, pursued to the extreme, would lead us to ascribe an immaterial spirit to steel and amber, and other material substances, is not the only cause of the frequent, but false doctrine, that the matter is not wasted by the pictures of the imagination and combinations of thought. Commonly the artist or literary man is compared, not with persons who live quietly and in indolence as regards their thoughts and sensations, but with the corporally active artisans. In this case it is too readily forgotten, that while in the intelligent workman the brain is not inactive, the change of matter excited by mental exertion in most artists and literary men is moderated by their sedentary lives; and yet an increase of the temperature of the body and of the desire for food does actually take place in consequence of mental effort. Artists and literary men, as well as the artisan, have to compensate, by a greater supply of nutriment, for the increased consumption, which transforms the essential constituents of their brain into the decomposed ingredients of their excretions. It is well known, that, notwithstanding their sedentary life, artists and literary men suffer from corpulence; and no one expects to find that store of the more constant constituents of the tissues, and which we may term fat-formers, as characterizing men of mental activity, excelling by their accomplishments in art or science. A large body and fleshy face may be suitable for monks and gluttons longing for repose, but it is not adapted for men of intellect. Abundance of fat in the blood of the brain paralyses thought, and hangs lead upon the wings of the imagination.

As a sedentary life renders digestion and the formation of blood difficult, and moderates the secretion preceding decomposition, which is increased by the activity of the brain, the artist and literary men have to choose, within the limits of a nutritious diet, the more easily digestible aliments. A well-baked bread and lean meat, combined with young vegetables, and such roots as are easy of digestion and contain a considerable proportion of sugar, form a wholesome diet for thinkers and poets; a large quantity of leguminous seeds, heavy bread, rich pastry, and greasy meat, create those irritable, morose, and almost always slender statesmen, who have permitted melancholy thoughts and gloomy imaginations to eclipse all happier views of life in them, so that they have come to consider rods and fetters as the most important promoters and protectors of civilization.

Well-seasoned aliments and stimulating beverages, if not taken in excess, are to be recommended to all men whose toil is principally mental, for a twofold reason. Spices, beer and wine, tea and coffee, if moderately taken, stimulate the different digestive glands to an abundant secretion, and therefore promote digestion, which in a sedentary life is so apt to become sluggish: this is one aspect of their usefulness. The other aspect bears directly on the brain: as the activity of this organ predominates it requires a constantly-renewed stimulus; hence the heating spices, with wine, coffee, and tea, are appropriate and useful, imparting a bolder sweep to the mental activity, which creates images and combines thoughts into judgments. The oftener the stimulant is used, the greater is the quantity required on every subsequent occasion, in order to produce the same degree of excitation. This continually augmenting waste originates a habit, and impairs sensibility; for the frequent repetition of the excitement produces exhaustion, and the exhausted organ is only able to perform its peculiar function when the stimulant acts again; this would indicate that a frequent change in the mode of living is necessary. There are many literary men who cannot write successfully until they have increased the activity of their brain by tea and coffee, and in some rarer cases by wine. I say in rarer cases by wine; for while, from its action upon the judgment, tea is especially proper for the literary man, and while coffee, by animating simultaneously both the judgment and the imagination, belongs alike to the literary man and the artist; wine is the most appropriate beverage for the latter, who demands, above all, that his diet may stimulate the imagination, sharpen the senses and the memory, and facilitate the combination of ideas.

Provided only that a certain limit is observed, there results no disadvantage from the use of stimulants; if they are taken to such a degree that exhaustion sinks into a complete numbness, the greatest quantity of the strongest stimulant becomes at length ineffective. When by habit, however, the stimulant has become a necessity, an enervating relaxation infallibly follows, as sometimes mournfully illustrated by less prudent literary men. The stimulant ceases to excite—the debilitated organs have already been indebted to it for all the activity it can give. In this case the victim continues to seek his refuge, until dangerous diseases of the stomach cripple the digestive powers; with the decay of the digestive organs the formation of blood and nutrition are disturbed; and with the digestion vanish clearness of thought, acuteness of the senses, and the elasticity of the muscles.

§ 102. **Diet in Summer and Winter.**—In considering the wide diversity between the modes of life of the inhabitants of the tropics and the temperate and frigid zones, one is induced to suppose that temperature must exercise an essential influence upon the change of matter.

This supposition has become a certainty. It has long been known that in a high temperature the evaporation from the skin predominates, while in cold weather a greater proportion is excreted by the urine. This increase of urine, which in health is maintained during the whole winter, is accompanied by an abundant formation of urea. From these observations, it would appear that a higher temperature diminishes the quantity of carbonic acid exhaled in a certain time, and consequently that by warmth the two most important products of decomposition are diminished; it becomes indubitable that in summer the excretion is weakened, and in winter increased. To the excretions correspond the nutrition, the formation of blood, and the digestion; hence results the necessary conclusion, confirmed by daily experience, that in summer we digest a smaller quantity, and that more slowly.

The relaxation caused by frequent and abundant respiration renders digestion more inactive. Inasmuch as the formation of blood and the nutrition of the tissues progress more slowly in summer, we are then less fit for any kind of exertion than in winter; and since we observe this difference the most strikingly when a rapid change has produced a great alteration in our excretions, it is apparent why a walk or any violent movement so readily tires, when the rough, damp, and cold weather, amid which the winter so often takes its leave, has suddenly yielded to a sunny spring day. It is only when we have become gradually accustomed to the less active change of matter that the expanding life of the vegetable world, awakening in the freshness of its verdure, delights us,—that the alluring strains of the songsters of the grove exert their full influence upon our nature; but with the retarded movements of the change, all these impressions, effective as they are, invite us rather to tranquil enjoyment than to a vigorous activity. If the "*dolce far niente*" first exhibited itself under Italy's warm and serene sky, with us the sweet delight of calm sensations, the intensity of which is seldom disturbed by energy, is the privilege of spring: May is the month of love and enjoyment.

But if in autumn, when the oppressive summer days have passed, there suddenly appear much cooler but more genial weather, we feel impelled to a cheerful assiduity. The quicker movement of matter carries us along as it were with the flowing stream; and we often see achieved in a few days, what had lain in our mind for weeks without our having been able to find the right disposition to attempt its accomplishment.

These differences, however, are most observable in labourers with the brain. Those who rely on their bodily exertions and are never out of exercise, are as active in spring as at other times. And naturally so; for in the restless circuit of cause and effect, which the change of matter embraces, they increase by their energy the movement of the matter; and while the artisan continues with an industrious hand to labour for a living for himself and his family, while the farmer looks forward to the encouraging reward of his labour in a rich harvest, which he extorts from the soil by his activity, and for this shuns neither heat nor labour, the changing matter of his system remains equable and well balanced.

No influence, however, passes without some effect. While, therefore, in summer, as at other times, occupation and age, habitude and sex, unite with temperature in determining the choice of food; certain rules may be clearly established, if in this series of combined and mutually reactive influences we separately consider heat and cold.

In summer the desire for food is diminished, because the consumption of the tissues is less; a smaller quantity of nutritious food, or less nutritious but easily digestible aliments, are to be taken. The meat of young animals, young vegetables, edible roots containing abundant sugar, fruits and salad, are also much relished in summer. The predilection for cooling beverages at this season has a perfectly rational basis, as the heat frequently produces palpitation, while the less rapid decomposition of the tissues, which is peculiar to the warm season, retards the transformation of the blood. Cooling and diluting beverages containing vinegar, currant-juice, raspberry-vinegar, and water, operate against this retardation; but the palpitations are only increased by heating beverages and spices. An abundance of spirituous liquors is, therefore, doubly injurious in summer; for the alcohol deprives the constituents of the body of the inhaled oxygen which is necessary for this decomposition, and also for the animation of the corporeal functions. For this reason, in summer the lighter sorts only of beer and wine, which contain a small proportion of alcohol, ought to be chosen. It is also important to be moderate in the use of heating spices, or to allow them only where a certain excitement of the digestive activity, within the limits of health, is wished for.

The greater expenditure which distinguishes the winter, necessarily requires greater supplies. In this season, therefore, the increased wants of the appetite have to be satisfied, and the more nutritious aliments, with those which are more difficult of digestion, are with good reason selected. The latter are easily mastered by the augmented digestive power, while the greater proportion of alimentary principles, contained in the former class, is gradually transformed into the constituents of the blood, and slowly conveyed into the circulation. Farinaceous food, containing a large proportion of gluten, dry leguminous seeds, and fatty pork, are in winter much more easily digested than in summer. In winter the fat is much more easily burnt into carbonic acid and water, as is proved by the increase of the carbonic acid which we breathe out in winter. The oxygen which is taken in also acts more vigorously. Although the fats, on account of their abundantly proportionate amount of carbon and hydrogen, are easily combustible, yet they differ from the albuminous substances, as well as from the constituents of fat, in requiring a greater proportion of oxygen in order to be really burnt. In summer, therefore, and in hot climates, where the oxygen is less efficient, the fat of the food is digested with much greater difficulty; hence the preference given in the tropics to the constituents of fat over the fats themselves, is a circumstance arising from natural laws. So long back as the times of Herodotus, we know that in hot climates people lived chiefly upon a vegetable diet. The inhabitants of the islands of the Pacific Ocean very seldom eat fish of any kind, and pork and fowl only at festivals. The food of the negro is rice, millet-seeds, maize, and roots containing a great quantity of starch. The chief meal of all inhabitants of the tropics consists of rice. Here we meet also with an illustration of the not unfrequent fact that a custom, apparently traceable to superstition, is really founded on a deeper and more rational foundation; for inasmuch as at a high temperature fat is less easily decomposed through the diminished activity of our lungs, a correct interpretation of natural phenomena has led to the entire prohibition of pork during summer to the inhabitants of Southern Italy, and altogether to the Jews in Palestine. Obedience becomes superstition only when it continues to exist after the reason for the law has ceased.

If in summer everything must be avoided which absorbs the oxygen so necessary for the organic constituents of the body; so, on the other hand, aliments may be taken in winter, which moderate the decomposition of our tissues, produced by the oxygen; hence we can bear in the winter not only a richer diet than in summer, but those beverages are also relished which by their abundance of alcohol retard the consumption of the constituents of our body. It is inconceivable to me how physiologists can preach the renunciation of brandy, when I consider the simple fact, that the further north the greater its consumption. While the inhabitant of the South of Germany is satisfied with the proportion of alcohol which he takes in beer and wine; in Northern Germany, Holland, and England, brandy, gin, and other spirits are taken; but the Russians, Swedes, and Norwegians consume a still greater abundance of spirits. In a very instructive public lecture at Mayence, Von Kittlitz stated that the Kamtschadales, who are generally remarkable for their great respect of property, often steal brandy, but afterwards, with child-like simplicity, confess their theft, avowing that they could not do otherwise: they only steal what they consider a necessary of life. This regular increase in the consumption of alcohol, corresponding to the nature of the climate, cannot but suggest the existence of some valid reason for this popular custom, which has been completely confirmed by scientific investigation. The alcohol which has been taken is a new source of the development of warmth, by which, on one hand, the food is more slowly consumed; and on the other, the cushion of fat under the skin, which is a bad conductor of warmth, and sufficiently protects the system against external cold, is kept from wasting. Travellers who have visited the Polar Seas unanimously assert, that in such voyages Europeans could not exist without spirituous beverages. In low, cold, and damp countries, experience has always proved spirituous beverages, taken in moderate quantity, to be useful.

It is true, science as well as experience warns against excess. When spirituous beverages have been taken in abundance, the venous and arterial blood have been found alike in composition, and in animals even fits of suffocation have been observed. It is apparent that the oxygen which alcohol takes up in order to be transformed into acetic acid and water, and then into carbonic acid and water, is withhold from the constituents of the blood; while it is upon the combination of these matters with oxygen, one of the most important conditions on which a healthy change of matter depends, that the transmutation of the venous blood into the arterial takes place.

This circumstance ought always to be kept in mind; for then only do we restrain our fellow-creatures from intemperance, when we distinctly inform them that its injurious consequences are founded upon a necessary natural law, and therefore infallible. A rational intelligence is the sole basis of all real morality. By total abstinence, and under the form of a solemn undertaking, you create slaves of an irrational promise, and treat men no better than animals, which you shut up in a stable that they may not stray too far away.

Inasmuch as man is formed by all the circumstances conjointly, whose influence upon diet I have endeavoured to describe in this treatise, the rules laid down must be separately considered. The nature of man is the product, or rather the sum of all those effects of parentage and country, age and sex, position and habits, and even of the time of the day and year, which I have referred to. It is for the reader to determine the choice of food, according to the individual influences—bearing in mind that other circumstances to which we have not alluded still remain for consideration. These combinations of circumstances are nearly as numerous as the men themselves; and it must be left to the judgment of the individual to accommodate his diet to his own particular case.

All that I have written bears exclusively on man in a healthy state. "But in disease?" I hear you ask. It is just when the activity of the bodily functions deviates from the ordinary state of health, that the question of diet is the most important; and should not the book contain some instruction bearing upon this condition?

As truly as I am convinced of the usefulness to the people of a treatise on food for the healthy, so certainly do I know that I should only do mischief by giving here rules for the selection of food, of beverages and condiments, in disease. One point only is of the highest value in daily life; intemperance may become the source of the various diseases. This affirmation in its widest sense bears on the use of aliments of every description. And this general statement renders superfluous any attempt to explain why in autumn, for instance, the abuse of fruit will cause diarrhœa or dysentery; why meat immoderately taken may occasion the formation of calculus; why from an excessive use of spirits, gout or cancer of the stomach may origiate. Such an attempt would be without any bearing in practical life, neither could it be justified on scientific grounds; for in the present state of our knowledge, it is absolutely impossible popularly to describe, with a proper chain of deduction, intemperance as cause, and the various diseases as effect. Such a description would require so thorough a scrutiny of each particular case, with so detailed a consideration of the condition of the body, that either superficiality would annihilate its value, or profundity destroy its clearness. The doctrine of the causes of disease, presupposes a thorough knowledge of disease itself; and this requires a considerable familiarity with all the more important laws of science.

If this is the case as regards the knowledge of disease, it is much more so with regard to diet when under its power. Only the man who has devoted his whole life, with all his powers of sense and thought, to the investigation of the condition of man in health and disease, can unite with the necessary knowledge the more subtilely discriminating judgment under such circumstances; and that only after the most accurate account of country and training, of climate and weather, of age and sex, of habits, occupation, and of parents. No one would require this if he considers that every action has its necessary consequences; that the widest experience only, purified by the clearest judgment, and after careful personal examination, is able to secure in the individual case the desired effect with any degree of certainty. Render, therefore, to the medical man that which is his, yet without neglecting, for the healthy state, the study of those rational rules of life which are given by science,—for man is only obedient to such laws as he understands.

While solid and liquid food furnish the matter which is decomposed in our body and circulated through it, and by which we think and feel, nature and mankind exercise so continuous an influence on our senses, that the material of our body is never for a moment at rest. In never-ceasing motion, sensation and thought, will and action, are hurrying on; and if all this activity is only sustained by matter, all effects being but the result of matter acting upon matter, nevertheless the less material impressions of sound which elude our grasp, with those of light and colour which are altogether intangible, are no less important, and to many persons, indeed, much greater, than the alterations which food so infallibly produces in us. It becomes the wise man to recognize this dependence; and it is true piety heartily to feel this connection with the mighty Creator of all. Justly has Schleiermacher designated the sense of dependence in the individual, the true essence of all religion.

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ON FOOD ADULTERATIONS.

No evils are so pernicious as cumulative evils; and paradoxical though the assertion may seem, the aggregate result of a cumulative evil is the more considerable as the evil itself is small. One large dose of arsenic or corrosive sublimate involves a contingency of sufficient danger; but such accidents are fortunately rare, and the subject of arsenical or mercurial poisoning would at least not have to lay to the charge of either of these poisons the quality of insidious nocuity. To an individual of ordinary intelligence, the symptoms of poisoning would, in nearly every case of this kind, be evidence enough; and few indeed would be the instances of false diagnosis to a medical man. Far otherwise is it when noxious agents are ingested day by day in articles of food or drink. Take, for example, an instance of insidious lead poisoning. It is a fact too popularly known for comment to be necessary, that water, under certain conditions, acquires the property of dissolving, and holding in solution, the metal, lead; whereas, under other circumstances, water may be transmitted through leaden pipes, and stored in leaden vessels with perfect impunity. The conditions of this safety and this danger will be fully explained hereafter. I so far anticipate the subject now, to illustrate the case of cumulative and insidious detriment to health by reference to the continuous ingestion of small doses of lead. Let us assume the existence of a pump with leaden pipes descending into a well, that well containing water of the variety which dissolves, and holds in solution, lead. It may be that the quantity of metal dissolved is so trivial that the water shall be altogether insipid; and that one draught, or two, or ten, would be as harmless as the same water might have been had lead never come into contact with it;—yet let a draught of such plumbiferous water be swallowed day by day for a continuous period, and the direst results almost necessarily follow. Firstly, vague symptoms of lassitude and general depression seize the members of a family thus circumstanced; colic then follows, then paralysis, and finally death, if discovery of the causes, and succour, be not at hand.

Perhaps there can be no better illustration of the danger to be apprehended from the cumulative effects of continuous small doses of a noxious body, than is furnished by the case to which the reader's attention has been directed. That case will be readily seen to present the type of many others, differing in degree of course, though corresponding in the general quality of insidious nocuity. It is the type of the insidious evils attendant on the ingestion of adulterated food and medicine. Perhaps the adulteration of medicines is the graver matter of the two—seeing, that whilst food is eaten by people in both health and disease, medicines especially concern the latter state. The stomach of an individual in health is an organ of wonderful endurance—of great accommodation. The usages of civilized society are such, that what with elaborate dishes and condiments, hot drinks and spirituous stimulants, the stomach is accustomed to such an amount of ill-treatment, that the ingestion of many substances, themselves noxious, are scarcely more noxious than the normal ill-treatment which a civilized stomach is educated to bear. Practically, therefore, the ingestion of such noxious bodies may scarcely eventuate in a perceptible result. Far otherwise is it in the case of medicines taken into the stomach of one whose susceptibilities are feverishly aroused, and his senses morbidly sharpened. Any unwonted shock to the system, any error of calculation in the dose of a medicine, or (what amounts to the same thing) in its calculated power—whether as to degree or to kind—may act the part of the direst poison, and kill at once, though an influence of precisely the same kind, and degree, might count for nothing to a person in health.

Although it be not easy to draw a line of strict demarcation between food and medicines, considering the easy gradations by which one class merges into the other; nevertheless the object of the succeeding pages will be to deal, as exclusively as possible, with the subject of adulterated food.

The term Adulteration defined.—All who have attentively read the minutes of evidence tendered before Mr. Scholefield's committee on adulterations, cannot fail to have been struck with the ill-defined ideas attached to the word, adulteration, by the major part of the individuals examined. Putting aside the grave issues involved, it is somewhat amusing to remark how extremely shocked many gentlemen were at the words adulteration, contamination, impurity, &c.; even while not merely explaining, or palliating, the acts to which such words applied, but openly defending them. It is to be presumed that, after the mass of evidence tendered, some legislative enactments will follow, having for their object the prevention of food adulteration; but it is a matter of great regret that some clear definition of what is meant by adulteration, contamination, impurity, &c.—clear, that is to say, in a legislative sense—has not yet been arrived at.

Various as were the shades of opinion manifested on this important subject by the different witnesses examined, the aggregate of testimony leans towards the adoption of what I cannot but regard as a fundamental error; viz. the adoption of the idea of nocuity as necessary to constitute an adulteration, in the legislative sense, of an article of food or drink. Now, unquestionably the idea of nocuity is intimately connected with the idea of adulteration or contamination of vital ingesta; but the logical precision of philosophy is violated, and the application of that philosophy will be rendered abortive, by adopting a definition of purity, or contamination based upon a previous determination of nocuity, or innocuity. The discrepancy of medical opinion as to the relative innocence or nocuity of articles of food is proverbial; and not more proverbial than easily explicable—the fact being that in by far the greater number of instances, no absolute rule admits of being laid down. If human constitutions and idiosyncrasies were precisely similar, some correct deductions might be arrived at; but the physical temperament of our bodies is no less various than the traits of human features. Articles of food which agree perfectly with some constitutions, disagree even to the extent of being poisonous with others. I know an individual who invariably suffers from cutaneous eruption, of erysipelatous character, after partaking of crab; and the instances are frequent of persons who dare not eat some particular kind of fish; amongst which salmon is conspicuous. Here are types and indications, then, of the interminable fallacies which would result from the adoption of the idea of innocuity or nocuity as a basis of definition for the terms, adulteration, contamination, impurity, &c. When to organic and radical fallacy, which attaches to a definition connected with the preceding ideas, and based upon them, are added the bias of interest and the disturbing influences of commercial expediency—when these disturbing elements are reflected on, the conclusion is inevitably arrived at that a thing will be pronounced noxious or innocuous according to the interests involved.

A great error has been committed, not only by the public generally, but also by professional men and legislators, in understanding the word impurity and its congeners in an absolute, instead of a relative sense—than which nothing can be more unphilosophical. Hence, the words impurity and adulteration, as applied to articles of food, have come to stand for something injurious to the human organism. If food were alone in the category of adulterated articles, there might not practically be much objection to the acceptance of this popular notion, though in any case it is based on a secondary and specific quality—a basis generally devoid of the most correct elements of scientific classification.

In attaching a limiting significance to the terms adulteration, contamination, and their congeners, it would be as unphilosophical as injudicious to alter their meaning for every class of bodies. Whatever definition of the terms be held to suffice in the case of articles of food, those terms should be sufficiently general to include all other cases of adulteration and contamination. Accepting this postulate, we must of course banish the ideas of nocuity and innocuity to the human organism, and acknowledge, as our foundation of the idea of adulteration, the principle of deviation from a standard. In proportion as the idea is embraced, so does the subject of adulterations become more clear, more succinct, more easily cognizable to the legislature; in proportion as this idea is departed from, so does the subject become more vague and undefined. Adopting this idea on its abstract merits, and contemplating the subject of adulterations in accordance with it, we shall soon find that these abstract merits are associated with an important practical issue. The premises once accepted that every deviation from a given standard is to be recognized as an impurity, adulteration, or contamination, we are soon led to the sound dictum of practical morality, that a purchaser should have that which he demands—if not an interdicted thing; and that any deviation is a fraud, a contamination, or adulteration.

Substances Present in Minute or Infinitesimal Quantity.—Every person acquainted with chemistry is aware that many substances are discovered in places, and under circumstances, where they would be little suspected. The chemist is perfectly well aware that he cannot take a feather, or a piece of flannel, however old, and worn, and washed the latter may be, without discovering in both evident traces of sulphur. Equally well the chemist knows that gold, scarce though it be as to gross amount, is one of the most extensively diffused of all bodies; not to mention its wide mineral distribution, and its presence in some vegetables, according to Dr. Percy gold is found in all oceanic waters which have come under his examination. In like manner, the chemist is aware that it would be impossible for him to subject any specimen of bread to analysis without discovering in it traces of various metals. These indications furnish only particular cases of the general proposition, that without the idea of a limit the most incorrect notions will arise from a literal acceptation of chemical expressions. Let it be assumed that a person sends a specimen of bread to a chemist for examination; the chemist subjects it to the scrutiny of his art, and replies that amongst other constituents he finds in it lime, as he assuredly would also find sulphur, phosphorus, and other bodies, the names of which are equally startling. How incorrect would be the resulting notions created in the mind of one ignorant of chemistry! Much of this kind of alarm has actually arisen in the public mind, owing to misapprehension respecting certain bodies, the presence of which is only true to the limit.

As a natural consequence of our free institutions, and our independence of action, the deceptive tricks of contamination have been perhaps carried to a greater extent in these isles than elsewhere; nevertheless it cannot be denied that the subject has been lately brought before the public too much in the spirit of partisanship for the interests of abstract truth to be well subserved. Unfortunately, in this matter as in many others of cognate nature, the growing evil of purchased scientific special pleading has too often taken the place of scientific evidence; and thus much information that might have been temperately and profitably conveyed to the public for their own protection, has been wilfully distorted by high-wrought deceptive statements, into *nearly* the semblance, and *quite* the significance, of positive untruth.

As an example of this sort of scientific deception, the subject of aluminized bread may be adduced. Whether the presence of alum in bread be injurious to the human organism, or the contrary, I shall not discuss here, this being a secondary issue, not intimately connected with the topic to which I purpose to advert. Injurious or not injurious, the addition of alum to bread involves the addition of that which is foreign to the standard of bread as ordinarily accepted, and which, *pro tanto*, constitutes an adulteration or contamination. Reviewing the scientific evidence which has taken place on this subject, it will have been noticed, that not only is the question of the nocuity or innocuity of alum still open to the greatest doubt, which, indeed, may well be as the consequence of honest difference of opinion, but the very presence or absence of alum in bread, to the original materials of which alum was added, has been debated by opposing scientific evidence in a way calculated to mislead the public. Those scientific witnesses who aver that alum, though added to the materials of bread, does not exist in the bread itself, can hardly be said to have acted up to the poor standard of morality chosen by themselves; they can hardly be said to have been true to the word. Even assuming, as they desire to assume, that alum—a salt made up of potash, alumina, and water—loses its water by the amount of heat employed in the operation of bread-baking (a most improbable assumption, by the way), still it is hardly true to the letter to assert that alum minus water is no longer alum. In spirit, so egregiously untrue is the expression, that it is perhaps even worse in its consequences than a falsehood pronounced as such, because it is more insidious.

With every desire that some efficient legislative provision should exist for securing the purity of things in general, but more especially of articles of medicine and alimentary ingesta, I cannot but think that the subject of aluminized bread has occupied a specific attention which might have been more profitably directed to the subject of adulterations generally. To my appreciation, the point has never yet been satisfactorily made out that alum, in the quantities ordinarily used by bakers (and without expressing this limitation, all discussion of the subject would be absurd), is more injurious than common salt.

Legislative Measures having reference to the Adulteration of Ingesta.—The principle of *caveat emptor* is one peculiarly congenial to the British character and British institutions. The jealousy of our race, in respect of all that relates to interference with the freedom of the subject, is, perhaps, the most remarkable trait in our political aspect. Amidst much that is good, traceable to the unrestrained expression of this self-dependent principle, there is unquestionably something of evil; and of the latter, the subject of adulterated ingesta furnishes an apt example. By the term ingesta we may for the present understand not only articles of food and drink, but of medicines also,—anything, in point of fact, which is taken into the stomach.

Now it will be evident, on the slightest inspection, that the principle of *caveat emptor* has not, *cannot* have the remotest significance in many cases of the purchase of articles of food; and still more emphatically does the remark apply to the majority of cases involving the purchase of medicines. Limiting our present observations to the case of the purchase of food, it will be evident that the means or power of discrimination at the purchaser's command are, for the most part, of the slightest and most inefficient description. Debarred from the evidence of chemical and microscopic examination, the purchaser, for the most part, has no other rule of guidance than that furnished by the direct exercise of his senses; but this direct application of the senses is, in the majority of instances, and those of the greatest importance, totally inoperative. No person, by the direct application of the senses, could discover the presence of lead in wine, or cider, or sugar, though the lead might be present in a highly dangerous quantity; no one, by the direct application of the senses, could prove the existence of copper in pickles or confectionery, though copper might be present to a dangerous extent. These examples, involving the presence of bodies confessedly noxious to the animal organism, have been purposely chosen for the sake of illustrating the non-applicability of the dictum *caveat emptor* in extreme cases. Were we to investigate the instances of adulteration not involving the presence of bodies confessedly injurious to health, examples might be found almost *ad infinitum*.

Supposing, then, the determination to be arrived at that some legislative supervision shall take place, with the object of protecting the public against falsifications, against the presence of which they cannot protect themselves, the important question arises, How is this supervision to be accomplished? Shall the supervision be exercised by the chemical department of the Inland Revenue, or by sanitary officers to be specially created? Shall there be a metropolitan board of examination, or shall each district have its own local board? At whose instigation shall the examination of the materials of human ingesta take place? And, lastly, who shall assume the functions of prosecutor? These points have been much discussed, without any definite result having been as yet arrived at.

In these general remarks, although exception has been taken to that definition of the terms impurity, contamination, adulteration, &c., which presupposes the presence of something injurious to health, I would by no means wish the reader to understand that the hygienic point of view is not the most important from which the subject of public bromatology can be contemplated. Nevertheless, it seems unphilosophical, and therefore highly objectionable, that the previous conditions of nocuity and innocuity should be involved in a definition—conditions in respect of which there is often the widest divergency of opinion, when the far simpler, far more philosophical rule of guidance of giving the purchaser what he asks for, can be so easily adopted.

This is a rule of guidance which, in its principle and its application, is unlimited; whereas, if we adopt the principle of limiting the terms adulteration, contamination, &c., by the previous assumption of the qualities of nocuity and innocuity, not only do we introduce a never-ending topic of dissention, but we narrow the scope to which legislative enactments bearing upon the subject can be applied.

Having premised these general remarks, I shall now proceed to set before the reader a short summary of the chief contaminations which are prone to exist in certain common articles of food, whether the result of accident or design.

Bread.—This most important article of food of civilized man is frequently adulterated,—occasionally with bodies which are in themselves innoxious, and the presence of which in bread corresponds *pro tanto* with so much nutritive matter absent, but not unfrequently with bodies which are actively and positively injurious. The fruit, commonly termed seed, of all the cereal grasses is capable, when ground, fermented, and baked, of yielding bread. Wheat, however, is pre-eminent above all others as a bread-making material. In all English towns, and in by far the greater number of English rural districts, wheat is supposed to be the sole bread-making staple; but in many parts of the continent, especially Germany, rye is commonly employed. Rye bread in these isles is rare, though barley bread is more common.

Assuming wheat-flour to be the staple of ordinary English bread, let us now see to what contaminations it is liable. These are of various kinds. Amongst the most frequent are the substitution or admixture of flour or meal from other species of graminaceæ; in this way rice is frequently employed,—not so much, however, as a mere article of substitution, as because rice-flour is highly hygrometric, absorbing water to a great extent, and holding it so pertinaciously that no heat employed in the subsequent process of baking is competent to drive it away. Flour of peas, beans, and the fruit of other leguminosæ, is also amongst the most frequent and the most innocent materials of adulteration. More reprehensible is the admixture of gypsum (plaster of Paris or sulphate of lime), bone earth, and, as in Belgium, occasionally sulphate of copper. Alum, too, is a substance wherewith bread is frequently adulterated, though the consequences of this adulteration, there is good reason to believe, have been considerably exaggerated. Potato-starch has been spoken of as being a material much employed for the adulteration of bread, but I believe the statement is founded on error. Not only does a quantity of potato-starch not exceeding two or three per cent. impart a disagreeable taste to bread, but it spoils the shape of a loaf to such an extent as would almost seem incompatible with its employment as a contaminating agent. Potatoes, mashed and fermented, certainly are employed in the manufacture of bread, but not, so far as I have seen, with the idea of adulteration. The fact is, that fermented potato-mash may be regarded as so much yeast, the place of which it takes, and enables the baker to diminish to a proportionate extent the amount of real yeast that would have been otherwise employed in the manufacture. Sago and tapioca, especially the latter, have been sometimes used in the manufacture of bread for the purpose of contributing a fictitious volume and weight to the resulting bread, without, of course, imparting a corresponding amount of nutriment. A curious instance of the employment of tapioca, as I believe, in the bread manufacture, came under my notice in the spring of 1854. A French capitalist was introduced to me professionally, in order that I might give my opinion respecting a new process of bread manufacture, the secret of which he had purchased. The capitalist, and also the solicitor who introduced him, were acting in perfectly good faith, though as much perhaps cannot be averred as respects the actual inventor. The proposition was most extraordinary. The inventor stated, that by a peculiar system of manipulation he could produce some 50 per cent. more bread out of a given amount of flour than could be produced by any bread-making process hitherto known; and he affected to solicit the most rigid tests that could be instituted. Of course, the proposition was ridiculous, as I duly informed both capitalist and lawyer; but they would by no means accept my dictum.

It was therefore ultimately agreed that bread by the new process should be made, and that samples of the result, mixed with samples of ordinary bread, should be submitted to me for examination, each sample numbered, but not further indicated. There was not the slightest difficulty experienced in distinguishing every sample of bread made by the new process from the other samples, from which they only differed in containing an enormous amount of water. Having been present when the bread-making operation was performed, I saw, but was not allowed to examine, the substance added: it had the appearance of a semi-gelatinous mass, and I believe it consisted of boiled tapioca. Rice flour would have had nearly the same effect, but to a less considerable extent.

Connected with the operation just noticed, the fact should be mentioned that the process having been gone through in the bakery of the Marylebone Union in presence of the guardians, the latter were unanimously satisfied, I believe, that the Frenchman's process was a real improvement, accomplishing all that the inventor professed to accomplish,—namely, the performance of the astounding miracle of generating some fifty per cent. of nutritive bread *out of nothing*. Perhaps no better proof can be adduced of the insufficiency of popular scrutiny, in cases at least which involve a consideration of the normal standard of articles of food.

Amongst the various schemes which have been had recourse to for increasing the amount of water in bread, the employment of boiled paste for setting the dough should not be omitted. A patent was taken out to this end some years ago by a foreigner. This slight variation of treatment, unimportant though it may seem, had the effect of enabling the baker to produce 104 loaves, each of 4 lbs., out of a sack of flour, instead of 94 loaves, as in the ordinary process of manufacture. Fortunately, this kind of bread rapidly mildewed in hot weather; the process was therefore soon abandoned.

Aluminated and Cupreous Bread.—Good bread cannot be made without the addition of common salt; but with the exception of this, the admixture of no other mineral substance with the materials of bread is recognized. For certain reasons, however, presently to be explained, other mineral constituents are employed; the chief of these being alum in this country, sulphate of copper (blue vitriol) in Belgium, sulphate of zinc, and more lately lime-water in Germany. It is, perhaps, impossible to present an unobjectionable theory of the use of these mineral substances. The fact is, however, undoubted, that, owing to certain causes, more especially the absorption of water and subsequent fermentation, flour of all the cerealia, and more especially of wheat, is liable to deterioration. This deterioration corresponds with, and is dependent upon, the loss of a certain amount of nutrient matter; and the flour, having undergone this change, cannot be made into bread so good as would have resulted before the fermented change took place. The addition of certain mineral constituents—more especially alum, sulphate of copper, and lime-water—remedies the deterioration (to the eye at least), and enables the baker to make bread apparently good out of inferior flour. As regards the quantity of alum employed, this varies according to the kind of flour manipulated upon, and the degree of deterioration to which it may have arrived. No sensible effect, however, is produced by employing less than the $\frac{1}{500}$th part of alum.

When sulphate of copper is substituted for alum, a very much smaller quantity suffices; and this is fortunate, seeing that sulphate of copper is intensely poisonous. An amount of this salt, equal to the one fifteen-thousandth of the bread to which it is added, suffices for producing the desired effect. According to Dumas, even one seventy-thousandth part of sulphate of copper, representing one part of metallic copper for three thousand parts of bread, produces a powerful effect upon the panary fermentation, though the maximum effect is produced by proportions lying between one fifteen-thousandth to one thirty-thousandth. Any considerable addition above the latter proportions defeats the intended object, rendering the bread green in colour, and imparting a disagreeable taste and smell.

Sulphate of copper never seems to have been employed in England for the purpose of bread-making: in Belgium, however, the practice is, or more properly speaking *was*, common. The addition of sulphate of zinc for a similar purpose does not appear to have been very prevalent anywhere; the fact being that it is not nearly so efficacious as sulphate of copper, and a larger proportionate quantity has to be employed before any effect is produced.

Liebig has lately suggested the employment of lime-water in the bread-making operation, as a substitute for alum. He states that lime-water is equally efficacious with that substance, and he believes more innocent. In point of fact, Liebig believes that certain forms of disease which are liable to attack persons who live too exclusively on bread, are referable to a want of lime experienced by the human organism. Far, therefore, from endeavouring to temporise with his culinary discovery, or speak of it apologetically, he strenuously advocates its adoption.

Detection of Alum.—This is a very easy problem of chemical analysis; nevertheless some general directions for its performance may not be inappropriate. About 1000 grains of the bread to be examined may be taken, dried, incinerated, the ashes digested with nitric acid, evaporated to dryness, and the soluble products of the evaporation taken up by warm water. A solution of caustic potash is now to be added, and the whole boiled, filtered, and treated with solution of sal-ammoniac. If alumina be present, a precipitate is formed after boiling. The amount of alumina may be ascertained by washing it, drying, incinerating in a platinum crucible, and finally weighing. Every 100 grains of dry alumina correspond with 664 grains of crystallized alum.

It is evident that in the analysis just described, the original presence of alum is inferred from the final determination of alumina. The following operation, devised by MM. Robine and Parisot, and referred to by Dr. Normandy, proceeds a stage further, and determines the presence of sulphuric acid, the second constituent of alum:—2000 grains of bread to be examined, stale bread by preference, are to be crumbled small, then macerated in water for two or three hours and squeezed through a piece of white linen. The liquor thus obtained is next to be filtered, the filtrate poured into a porcelain capsule, and evaporated to dryness by a steam-heat. The residuum being now treated by a small quantity of water and filtered, the filtrate is divided into two portions.

(1). One of the portions is treated with liquor ammoniæ, or a solution of sal-ammoniac; if a white precipitate fall, it is alumina.

(2). The second portion is treated with chloride of barium; if a white precipitate fall it is sulphate of baryta, and therefore characteristic of the original presence of sulphuric acid.

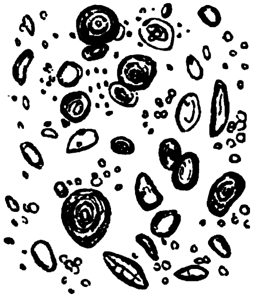
The conjoint teachings of these operations demonstrate the original presence of alum.

Detection of Sulphate of Copper.—The detection of this substance in bread is still more easy than the detection of alum. Like the preceding case, the operation resolves itself into two parts, one having reference to the detection of sulphuric acid, the other to the detection of the metal or metallic oxide. The relations of copper to colouring tests are very peculiar, as the chemist will not fail to remember. Among other characteristics of this kind, copper is one of the four metals, the solutions or soluble preparations of which yield a mahogany-brown tint with ferro-cyanide of potassium. Taking advantage of this property, the presence of copper in bread may be generally determined by moistening a crumb of the bread with solution of ferro-cyanide of potassium. If a mahogany-tint be developed, the bread thus tested must contain either copper, uranium, titanium, or molybdenum; but, practically, the absence of the latter three may be taken for granted. About one part of sulphate of copper in 9000 parts of bread may be readily detected by means of this test.

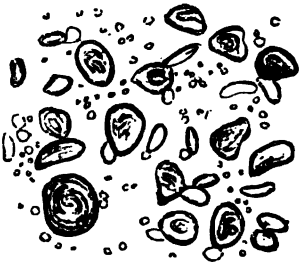
If it be desired to extract the whole of the copper from a given portion of bread, and estimate the quantity of copper quantitatively, another process must be adopted. A portion of the bread is to be incinerated, the ashes digested with nitric acid, evaporated to drive off excess of acid, taken up by warm water, ammonia added to slight excess, then a current of hydrosulphuric acid passed through, until all the copper is precipitated in the condition of sulphide of copper; from the final amount of which the amount of copper originally present may be readily calculated.

The substances already mentioned, although those with which bread is commonly adulterated, do not complete the list. Carbonate of magnesia has been a rather frequent adulterating material; so, in like manner, has pipe-clay. Unlike alum, the sulphate of copper, and the sulphate of zinc, neither carbonate of magnesia nor pipe-clay exercises a chemical effect on the constitution of the bread-stuff. Both are added with no other view than to improve the colour, and to increase the weight of the bread adulterated.

Discovery of the Foreign Vegetable Matters sometimes added to Bread.—Various chemical methods have from time to time been recommended for ascertaining the presence of foreign vegetable matters in bread. The warmest advocates of chemistry, however, must confess that their peculiar science is rarely so powerless and inefficient as when applied to this very case. On the other hand, here, in this class of operations, the microscope is all but omnipotent; by means of it, fragments of vegetable matter may be referred to their original plants with the greatest possible certainty. For this reason I do not think it desirable to set forth any chemical processes, but shall content myself by referring the reader to the microscopic delineations of several vegetable products which are occasionally mixed with bread. Those illustrations are admirably rendered in Dr. Hassall's treatise on Food Adulterations.



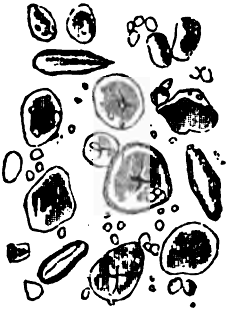
Starch granules of wheat flour.



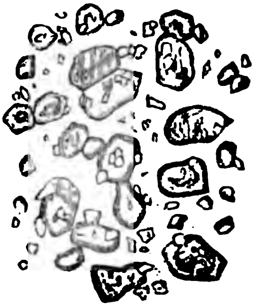
Starch and cellulose of barley.

Reference to these drawings of microscopic objects will readily demonstrate the physical difference between them—a difference so well marked that verbal explanation is superfluous.

Natural Deviations from the Normal Standard of Purity.—Besides the preceding and numerous other substances which may be added to bread materials by way of adulteration, others remain to be considered, the consequences of which may become very grave. All the cerealia, but more especially rye, are subject to a condition termed ergotism, dependent on the presence of a fungous growth. The grain thus affected turns black, grows larger and longer than naturally, is bent and deformed—its appearance, in short, is entirely altered.

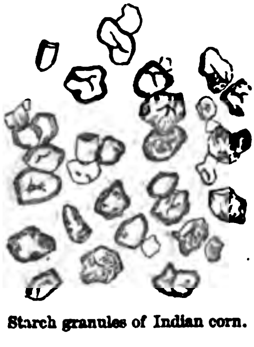


Starch granules of rye flour.

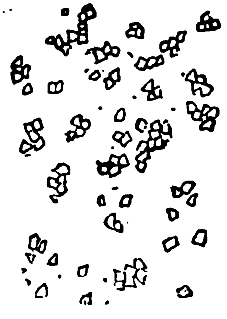


Starch corpuscles and cellular tissue of oats.

Ergot of rye is a powerful medicinal agent, being administered for the purpose of stimulating uterine contraction, and thereby shortening the duration of parturition. This is its medicinal use; but when it enters into the bread of a populace the most dire effects may intervene: abortions may ensue without apparent cause; they are endemic, and the populace may be totally unaware of the cause until symptoms of gangrene prompt the intelligent physician to inquire whether the bread of the district in question be not, to a greater or lesser extent, made from flour tainted with ergotism. As I have already remarked, the condition of ergotism is most prevalent in respect of rye; and for this reason—rye bread being little used in these isles—the diseases consequent upon ergotism are uncommon with us. On the continent, however, especially in Germany and France, the consequences have often assumed the degree and extent of a veritable scourge.



Starch granules of Indian corn.



Starch granules of rice.

Although the fruit of the cerealia may become detrimental to health by assuming the condition of ergotism, and although it sometimes assumes other undesirable, if not positively noxious states, yet the natural family, viewed as a whole, is characterized by a singular uniformity of normal innocence. Thus, whilst certain botanical families—such, for example, as the solanaceæ, apiaceæ, and cucurbitaceæ—yield products varying in quality from the extreme of innocence to the extreme of danger; as a rule, the graminaceæ present the uniform characteristic of harmlessness. This is a wise and a benevolent provision, seeing that the fruit of the graminaceæ is, in most parts of the world, a material out of which much of the food of man is prepared. Nevertheless, there are poisonous grasses; and the *lolium temulentum*, or poisonous darnel grass, is one: occasionally its fruit gets mixed with wheat or other bread-making grain, and danger to those who eat the resulting bread is the consequence.

Practical Generalizations.—It would not be difficult to materially extend the list of abnormal constituents in bread; but in this, as in all other matters relative to food adulterations, it is desirable to generalize and discover some comprehensive rule of guidance, rather than to collect an aggregate of incongruous details.

Bread being confessedly the staff of life, the basis or foundation of the food of civilized man, not ingested now and then, but regularly and continuously, the importance of seeing that it be not contaminated cannot be well overstated. Now in this, and in all other cases of contamination, it behoves all concerned,—and more especially does it behove the legislature (for the subject will have to be legislated upon before long),—to ascertain and define, and attach some precise meaning to the words, contamination, adulteration, and its congeners. Lately, we have heard something of justifiable contaminations; fine-drawn distinctions, too, have been made between the words adulteration, deterioration, and others, hitherto regarded as synonymous.

To recognize these distinctions would be fatal to the cause of dietetic purity; the best way of securing this I believe is the simplest way, namely, a legislative provision rendering it incumbent on the seller to let the purchaser have what he asks for. Once establish this principle, and we may cast to the winds all the numerous metaphysical distinctions which some people have endeavoured to establish between words naturally of parallel meaning; the condition of adulteration, contamination, or by whatever word we choose to call it, will no longer be accepted as something absolute, but as signifying deviation from a standard.

This definition is by no means new: it has been long adopted in science, and more especially chemical science. The chemist has no other notion of impurity or contamination, except the notion which attaches to deviation from a standard. By a sort of popular agreement, a certain idea of purity amongst metals, attaches to gold; nevertheless, if the chemist ask for pure lead, and obtain lead holding silver or gold, he will not hesitate to denominate the two noble metals impurities: hence, indeed, absolutely pure lead is a somewhat expensive metal.

There is reason to fear that no legislative proposal, having for its object to ensure the purity of ingesta, will be beneficially operative until it shall be founded on a recognition of purity or impurity, as understood by scientific men; in other words, deviation from a standard; until the fine-drawn metaphysical, and frequently incorrect, distinction attempted to be drawn between synonymous words shall be altogether discarded; and until, as a consequence, the question of nocuity and innocuity, often so difficult to ascertain, shall be discarded as the basis of a sufficient definition.

Of course, if we understand by the words adulteration, contamination, &c., departure from a standard, we must in all cases have previously fixed that standard. When, for instance, lead is admixed with gold and is said to be contaminated, we mean that the standard of pure lead is departed from by the amount of gold incorporated. Such is the principle; but how are we to apply it? How, for instance, is it applicable to the case under consideration, bread? Firstly, what is the standard of bread? what may be called its normal composition? Supposing the legislature to apply itself to the establishment of a legal or normal standard of bread, two classes of error, the very antipodes of each other, must be avoided; the error of chemical infinitesimals on the one hand, the error of undue margin or practical license on the other. Suppose, for example, that an Act of Parliament should broadly state, that pure or normal bread must not contain lime, or alumina, or copper, and a trace of lime, or alumina, or copper is discovered, no matter how small that trace may be, the ten-millionth or ten-billionth part—still the act would be contravened. Now lime is an invariable constituent of bread—the quantity is very small, no doubt, but still it is there; and, for aught that can be averred to the contrary, copper and alumina may yet be found in the cerealia. That neither *has* been discovered there I must admit, and alumina is characterized as confining itself very strictly to the mineral kingdom; nevertheless, no chemist, I imagine, will be disposed to aver that copper and alumina (the quantity of each regarded infinitesimally) may not be a constituent of bread-stuffs; at any rate, the accidental presence of either, in an infinitesimal quantity, may be conceded for the purpose of illustration. What then? Whether an infinitesimal trace or in a ponderable quantity, the words copper, lime, alumina, look equally large in print, the public would be equally terrified by baseless surmises, and the Act of Parliament would be prejudiced.

This bad consequence will only be avoidable by discarding terms relating to infinitesimal quantities, and fixing a legal limit. For example: in relation to bread, provision might be made that it should not contain more than a minimum per cent. of the metals of any class, that it should not contain more than a minimum per cent. of foreign vegetable matter, and so on by a similar process of exclusion for other classes of impurities. By this means all deviation from the legal standard would be more easily and more fairly controlled, than by regarding every impurity exclusively and exceptionally.

In the application of this scheme to the material bread, it is evident that the legislature would have to arrive at some conclusion respecting the properties of alum on the human constitution,—not its properties absolutely, but in connection with some particular minimum proportion; this way of approaching the subject would, I conceive, tend to sweep away many conflicting opinions which have been enlisted on both sides of the much-discussed alum question. The difference of opinion has arisen, I believe, chiefly from the circumstance of regarding in the absolute, that which should have been only regarded in the relative sense. Undoubtedly alum, when swallowed in a certain dose, is injurious; but so is common salt, and so is bread itself without salt; and, in short, so is the most innocent body imaginable, if ingested in undue proportions. The real question at issue in relation to aluminized bread, is the minimum dose at which it ceases to be injurious. On this point, medical testimony, however divergent on some points, would probably agree; and the result of this agreement could be embodied in the wording of a legislative measure. Alum is, as everybody knows, a compound of alumina, and alumina is the oxide of the metal aluminum; therefore an Act of Parliament, which shall state that bread must not contain more than a certain minimum of any metal or metallic compound, provides against an injurious dose of alum, no less than of other metallic compounds, and no longer gives occasion for the word-splitting and sophistry of scientific advocates.

Adulteration of Nutritive Starchy Matter.—Under the general designation starch, the chemist comprehends various substances which are held to be distinct in commerce, and which, indeed, manifest sufficient dissimilarity amongst themselves to warrant the distinction. These different starches vary in price and in estimation; hence a sufficient inducement for the sophistication of the most valuable, by the admixture of others less esteemed.

When starch of any variety, such as wheat-starch, potato-starch, or one of the various substances known by the generic name of arrowroot, is subjected to microscopic examination, it is found to consist of small vesicles holding a central nucleus. To this extent all varieties of starch agree; but when the shape and size of the particles of each individual variety are compared, great dissimilarity will be seen to exist. When treating of bread, this difference between the physical characteristics of certain varieties of starch was to a certain extent indicated. It will now be proper to extend these indications so as to include the numerous substances known commercially as arrowroot.

True arrowroot, that is to say Bermuda or West Indian arrowroot, is the starchy product of the root of the *Maranta arundinacea*. Arrowroot from this source is certainly more agreeable than from any other, and, perhaps, also more digestible and nutritious; for the circumstance cannot be too strongly impressed, that the actual nutritive power of a substance does not altogether depend on the chemical elements of nutrition which it contains: if it be disagreeable to the palate the stomach rebels against it, and the subsequent process of assimulation is incomplete.

West India arrowroot being the most esteemed is the dearest variety; it is, therefore, frequently adulterated with one or more of the other varieties now to be mentioned.

East India or *curcuma* arrowroot is, next to the West Indian variety, that most esteemed.

Some fifteen years since a variety of arrowroot, under the denomination Otaheite or Tahiti arrowroot, came into notice. This preparation was brought before the public under missionary auspices, and was much vaunted as superior to all other kinds. This assuredly it is not, although it is a nutritive and unobjectionable variety of dietetic starch. Tahiti arrowroot is the produce of the *Tacca coccinea*.

Two varieties of starch, sold occasionally under the designation arrowroot, are of British growth; one is common potato-starch, the other starch extracted from the Portland arum, and known as Portland arrowroot.

Sugar and its Adulterations.—Sugar is now so largely consumed by all civilized, and many uncivilized races, that it may be almost regarded as a necessary of life, and we only learn that it does not strictly come under such denomination by reference to dates at which it was unknown except in the extreme south-east of Asia.

The generic term, sugar, is applied to several sweet bodies of vegetable and animal origin. Thus, there is sugar of the cane, of grapes, otherwise called glucose, sugar of milk, sugar of mushrooms, and perhaps other varieties not very well determined. Sugar of the cane, however, may be regarded as the only kind which is prepared and sold as a commercial staple,—at least, this remark applies to this country; in France, however, large quantities of grape sugar, or glucose, are prepared for the purpose of imparting sweetness and body to wines deficient in those characteristics.

This is not a proper occasion for entering upon a description of the chemistry and manufacture of sugar;* I purpose confining myself, therefore, as narrowly as possible, to the consideration of substances with which sugar is contaminated, which render some slight notice of the chemical characteristics of sugar indispensable.

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* The reader who would enter upon these details is referred to my treatise, "On the Manufacture of Sugar, at Home and Abroad." Longmans, 1849.

Sugar, of whatever variety, is totally devoid of nitrogen, in which respect it resembles starch, and for which reason, like starch, it does not in the slightest degree contribute to the formation of muscle or flesh. It contributes to the formation of fat, however; and, in short, may be regarded as ministering to what physiologists term the respiratory function. No fact in physiology can be better established than the fact that an animal is unable to live upon sugar alone; nevertheless, sugar is an important article of diet.

The non-chemical reader, after perusing the sketch of sugar varieties just given, may, perhaps, have imagined it to be very incomplete. Several terms indicative of sugar varieties will, perhaps, suggest themselves to him; more especially beet-root sugar, maple, and date-sugar. All these seeming varieties of sugar, however, are varieties merely in the sense of their origin; all have precisely the same chemical composition, namely, 12 equivalents of carbon, 12 equivalents of hydrogen, and 12 equivalents of oxygen; which is also the chemical composition of sugar extracted from the cane. Hence the general appellation cane-sugar is applied; this term signifying, in the language of chemistry, not necessarily sugar which has been extracted from the cane, but sugar, the chemical composition of which is identical with that which exists in the cane.

When absolutely pure, after every associated matter has been separated, sugar, whether extracted from the cane, or beet-root, or the sugar-maple, or the stalks of Indian corn, or, in short, from many other sources containing sugar of the same type, is absolutely identical. The most refined palate, the most delicate chemical analysis, would fail to distinguish a variation. This is the real fact, although great misapprehension exists respecting it. Much of the confusion which prevails in this matter has originated thus:—Although the chemical variety of sugar known as cane-sugar is identical, from whatever source obtained, nevertheless the substances with which it is naturally associated in different vegetables is various. In the sugar-cane it is associated with an agreeable aromatic principle; so that the sugar-cane, where it grows, is a delicious article of food, or rather an agreeable condiment; but in the beet-root, the sugar-maple, and many varieties of the palm tribe, the substances with which sugar is associated are so disagreeable to the taste, that, until they are more or less removed, the sugar is unpalatable. If the associated matters be *quite* removed, the resulting sugar cannot be referred, either by the dictum of the palate, or of chemical analysis, or indeed by any means, to its particular source; but if portions of associated impurity remain, then there will necessarily arise recognizable, though collateral distinctions.

Of all the sources from which sugar is commercially extracted, the most impure source is beet-root. The substances wherewith sugar is associated in beet-root are so extremely offensive to the palate, that they must be absolutely separated before the resulting sugar can be accepted as an article for human consumption. For this reason it is that in France, Germany, Belgium, and other countries where beet-root sugar is made, no kind of sugar the produce of beet-root, answering to our description of yellow or brown sugar, is found in domestic establishments,—all is white or refined sugar. For the same reason it is that the treacle, which occurs as a secondary product of the beet-root manufacture, is rarely—I believe *never*—employed as an article of human food, but on the continent is fermented, and subsequently distilled, for the purpose of yielding alcohol.

Contemplating sugar with reference to the substances with which it may be deteriorated, it will be well, perhaps, to discuss it under the two leading aspects of white (*i. e.* refined or pure), and coloured sugar; understanding by the latter expression every variety of brown and yellow sugar. A very important fact in dealing with coloured sugars, is a subdivision collaterally involving the locality of their manufacture. They may be divided into coloured sugars produced in the colonies, and coloured sugars produced, as a collateral result, in the refineries at home. The latter, although frequently pleasing to the eye, are offensive to the smell and taste; chiefly because of the animal matter (*i. e.* bullocks' blood, or its derivatives) employed in the process of refining. I may here remark that the beautifully crystallized specimens of coloured sugar imported from the East Indies, and of which the sugar known as Dacca sugar may be considered the type, are not produced from the juice of the cane or immediately from any other vegetable, but is the product of a refining operation pushed not quite to the extent of making white sugar. Hence it follows that the East Indian sugars, so beautiful to the eye, are offensive to the smell.

Circumstances have thrown me very much into investigations of sugar manufacture at home and abroad. I have witnessed every process of sugar extraction, both from the cane juice and from the beet-root; I have also spent much time in many ordinary refineries; any processes, therefore, of sugar adulteration practised by the manufacturer I must necessarily have seen. I am able to aver that none such exist, if the case of the colonial manufacturer be excepted, who does not allow so much molasses to drain away as he might, simply because the legislature does not encourage him to export a very pure material.

Though it be quite true that the only pure sugar is white sugar, nevertheless there are many palates to which yellow or brown sugar, in other words *moist sugar*, is more agreeable. I do not, of course, allude to the vile brown and yellow products of refineries, reeking with bad animal odours, but of the purer sorts of colonial yellow sugars, these which are the result of vacuum-boiling in Demerara being considered the best.

The fact has long been known to medical men, that grocers, and others much in the habit of touching moist sugar, are apt to suffer from a cutaneous disease of peculiar character, very much resembling ordinary psora. When moist sugar is examined microscopically, the probable cause of this disease is revealed, in the presence of certain little animals to which the term *Acarus sacchari* is applied. Now ordinary psora, as medical practitioners well know, depends upon the ravages of another kind of acarus, the *Acarus scabiæi;* hence the theory which refers grocers' psora to the sugar acarus is exceedingly probable.

Dr. Hassall and other microscopic observers recommend the abolition of coloured sugar, and the consumption of white or refined sugar exclusively. Even supposing this idea could be carried out, there are many persons who would prefer coloured sugar, and who would continue to partake of it notwithstanding the presence of the little acari. Indeed it would go very hard with us if we should be debarred from eating and drinking everything which might contain animalcules. Nevertheless, the sugar acari are very ugly little beings; and if we needs must eat them, the less we know of it the better.

Lump or refined sugar cannot well be adulterated, either by the manufacturer or grocer, and a similar remark applies to crushed lump; but yellow or moist sugars are very rarely sold as imported. The grocer manufactures an article on which he can realise a given price, by mixing together either two or more colonial sugars, or colonial sugar with the coloured product of refineries. Here I believe the adulteration stops. It may have been the practice at one time to add to cane-sugar a certain mixture of grape-sugar or glucose—not obtained from grapes, but generated artificially by boiling potato-starch with dilute oil of vitriol. This practice has long ceased, for the very sufficient reason that it ceased to be remunerative when the potato crop began to fail. As regards the sand and saw-dust, which grocers are reported to mix with their sugar, I believe they have no better foundation than a popular prejudice.

If adulteration be considered as deviation from a standard, what shall be the normal or legislative standard of sugar? I believe a good practical standard would be created by the following limitations:—The maximum permissible quantity of insoluble matter should be stated; also the maximum permissible quantity of metallic bodies; the latter including, of course, lime, some of which is generally found in sugar. I do not think the legislature could profitably, or with advantage, attempt to fix a sugar standard on a more complex basis than this.

Much alarm prevailed some years ago, relative to a mode of purifying sugar by means of acetate of lead introduced by me; but the fact is, that sugar prepared by the process in question, contains less lead than sugar prepared by the old process. In the latter, not only are leaden-tanks frequently used, and the loaves fashioned in covers painted internally with white-lead, but no subsequent process is adopted for removing the lead. On the other hand, when acetate of lead is employed as a purifying agent, every minute particle of that substance is scrupulously removed by proper chemical treatment, and leaden-tanks, and, as much as possible, sugar-cones painted with white-lead are avoided.

Treacle and Molasses.—These terms are generally held to be convertible, nevertheless, they have a different significance, molasses being the saccharine liquid-drainage of moist sugar in the colonies; and treacle being the corresponding refuse of home refineries. Both treacle and molasses being the refuse of sugar—being, in short, an aggregate of all those substances generated out of sugar by the application of heat, and which cannot be crystallized—the composition of either necessarily varies. Inasmuch as bullocks' blood, frequently putrid, is employed in the refining operation, whereas no such animal admixture is used in the colonies; molasses should seem to be the less disgusting material of the two. I doubt, however, whether it merits this pre-eminence. The molasses-reservoirs in the colonies are haunted by a host of rats, cockroaches, flies, centipedes, and other creatures which swarm under a tropical sun. They enter, surfeit themselves, and die; thus perhaps contributing to the nutriment of molasses, but assuredly at the expense of sentiment and of delicacy. As regards treacle, the sugar-refiner will aver that no blood or derivative of blood can possibly find its way into that product, seeing, as he argues, that the process of charcoal filtration must necessarily separate it. Generally, I admit, the colouring matter of the blood is separated by charcoal filtration, not always, however;—its odorous matter is never altogether separated by that or any other refinery process, but ultimately finds its way into the treacle. There is no subject on which the susceptibilities of sugar-refiners are more delicate than that of bullocks' blood. Firstly, not liking to use the name, they technically call it spice. Many refiners, playing with the latter word, protest they do not use blood; and if hardly pressed, they will only own to an exceptional employment of it.

The export refiners have experienced considerable difficulty in relation to this blood-question amongst the subjects of the Emperor of Morocco, and other good Mussulmans. As regards the Turks, so civilized are they, that give them sugar white enough, it may have been fined by swine's blood so little do they care; less civilized followers of the Prophet, however, set more store on his precepts. With them, fond as they are of white sugar, it is a great point, that no blood shall have been used in its elaboration. Of this they are duly assured by little Arabic placards attached to the sugar-loaves; the evidence is satisfactory and the sugar sells. If, however, some Mollah, or other high ecclesiastical functionary, should ever put his nose inside one of our export refineries, he would perhaps ask himself the question—"Whence arises that fœtid smell of animal matter?" and he might feel afterwards inclined to scrutinize the veracity of those little Arabic placards.

Confectionery.—The subject of confectionery is so closely allied with that of sugar, that its consideration may with propriety be taken up in this place. The popular outcry against adulteration has never been raised with more justice than in reference to articles of confectionery. For the purpose of imparting agreeable tints, the kingdom of mineral poisons has been ransacked, and condiments otherwise innocent have been rendered not only positively injurious, but fatally noxious.

It is astounding to witness the extent to which the adulteration of confectionery has been pushed; and with no better object than that of imparting agreeable colours. In this way Scheele's green, a deadly preparation of arsenic, has frequently been used to impart greenness; and chromate of lead to impart a yellow colour. In the presence of these dreadful compounds, such matters as gypsum, chalk, &c., occasionally added for the purpose of imparting whiteness, sink into insignificance. When the subject of food adulterations is legislated upon, the presence of any metallic colouring agent should be stringently prohibited. Even were there no choice—even though confectionery should remain uncoloured in consequence of the objectionable mineral colouring matters being prohibited, the alternative should be readily accepted. It is nevertheless unnecessary; the organic kingdom yields a sufficient choice of colouring matters for all useful purposes of confectionery.

Pickles and Preserves.—Both these varieties of food are frequently contaminated; certain impurities being purposely added, whilst the presence of others is attributable to accident. Foremost in importance are the poisonous adulterations, and they chiefly refer to the admixture of copper. It unfortunately so happens, that copper is the only available metal for the purposes of manufacturing vessels of capacity suitable for the pickle-maker and wholesale confectioner. Iron vessels are inadmissible on account of the facility with which that metal dissolves, and the disagreeable colour it imparts. Iron vessels, lined with porcelain, answer well enough for small quantities, and at first. Vessels of this material, however, cannot be procured beyond very moderate dimensions; not only so, but the internal porcelain glaze, in process of time, cracks, and fails to be any longer a protection. Vessels of copper-tinned and copper-silvered are open to a similar objection, the protective coating wearing away after a time. Some of our large manufacturers of pickles and preserves have actually gone to the expense of providing themselves with silver vessels; but, notwithstanding the expense incurred, the material has not justified the expectations which were entertained respecting it. Every one must have noticed the facility with which articles of silver become black when exposed to the air under certain conditions, especially the air of cities: this blackening is attributable to the formation of a sulphuret, which is an objection to the use of silver vessels for the purposes indicated. A platinum vessel would, of course, be free from every objection, though the expense of first purchase would be great. Nevertheless, I wonder much that some of our enterprising pickle and preserve manufacturers have not incurred this expense. Taking advantage of the popular desire for non-adulterated pickles and preserves, I should think the purchase of a platinum vessel would be amply compensated. After all, the weight of platinum would be less than that required, and commonly used, by manufacturers of oil of vitriol. So long as oil of vitriol continued to be distilled from glass retorts, the liquid remained dear; it is only since the precious metal platinum has been substituted for glass, that oil of vitriol has been procurable at its present moderate rate.

Setting aside the difficulty of finding a substitute for copper, the beautiful green tint which it imparts to certain pickles and preserves holds out an inducement to its adoption. This green colour is peculiarly attractive in such preserves as greengages and bottled gooseberries, also in all pickles the vegetable components of which are naturally green; but persons who are attracted by the beauty of a colour, should reflect that it is only imparted at the cost of health, and by the incorporation of a poison. In the preparation of other than green pickles and preserves, the cupreous impregnation can of course lend no attractive tint, the manufacturer can have no inducement whatever to solicit its presence; but that presence is almost a necessity, so long as copper vessels are employed in the manufacture.

The remarks which have been made relative to the difficulty of employing other vessels than those of uncoated copper for the preparation of pickles and preserves, are only applicable to these operations on the large scale. For domestic purposes, iron vessels of adequate dimensions, lined with porcelain, can be obtained, and the tinned internal surface of copper vessels can be preserved in good order. It is well, however, to be aware that a tinned copper vessel, when a portion of the tinned surface has become abraded, is even more dangerous than a vessel of untinned copper. It is a well-known fact in chemistry, that any two metals being given, one of which is naturally soluble and the other naturally insoluble in any given fluid, the solubility of the former is much increased by contact with the latter. This circumstance depends on certain voltaic agencies, which need not here be described; suffice it to remember that the fact is undoubted.

Connected with the employment of copper vessels for culinary purposes, the curious fact should be mentioned, that oily matters, and certain vegetable acids, attack copper more readily when cold than hot. Guided by this knowledge, the cook should remember that it is dangerous to allow articles of food to grow cold in copper vessels.

Discovery of Copper.—Copper, whenever present, can be discovered with great facility. The first and most obvious presumptive indication of copper is the existence of a preternaturally bright green colour; this is, however, only a presumptive indication: specific tests must be employed if it be required to demonstrate the existence of copper absolutely. The facility of this determination will, *cæteris paribus*, be proportionate with the amount of copper present. If the metal exist above a certain proportion, it may be recognized by plunging a bright steel knife into a mass of pickles or preserves, allowing the knife to remain during a few minutes, afterwards withdrawing it, and washing it in water. If the blade of the knife be covered with a distinctly marked cupreous layer, no question can remain as to the existence of copper in the pickle, or preserve, thus treated. A very delicate test also, and one which in many cases can be brought into immediate requisition, is the following:—Add to a portion of the suspected pickle or preserves, some solution of ammonia (hartshorn), and remark the change of tint, if any, which ensues. If it be deep blue, the presence of copper is indicated. But to render the presence of copper evident with the greatest possible certainty—to extract it, collect it, and determine its amount quantitatively—another process requires to be followed. A portion of the suspected pickle or preserve must be dried, incinerated in a porcelain crucible, and acted on by some mineral acid, the excess of acid dispelled, the residue taken up by water. In this final solution, copper may be recognized with facility, by any of the appropriate tests for that metal, and if necessary may be precipitated by hydrosulphuric acid, and its amount determined quantitatively; this, however, is an operation which necessarily belongs to the professional chemist.

In addition to poisonous adulterations to which preserves and pickles are liable, there are others, innocent, sanitarily considered, but nevertheless objectionable, as involving deviation from a natural standard. Orange marmalade is frequently adulterated in this way, by incorporating with it other and less agreeable vegetable matter. Carrot-pulp has been in great requisition for this purpose.

Vinegar.—From pickles we are at once led to consider the adulteration of vinegar, concerning which some popular misapprehension has arisen, owing to the loose manner in which the word adulteration has been applied. This subject does not admit of rational discussion, until a standard of what is meant by vinegar has been arrived at—understood, at least, if not expressed. In all the reports of examinations of vinegar which I have seen, a modification of the chemical standard has been adopted;—that is to say, vinegar has been considered synonymous with acetic acid, and every constituent found in vinegar other than acetic acid (except indeed water) has been set down as an impurity or contamination. Now this standard of chemical purity is a guidance totally false, and illusory in many, indeed perhaps in all, cases involving dietetic solids and liquids. It is especially false as regards vinegar, water, and spirituous drinks, to none of which can the words adulteration, contamination, &c., be popularly applied without the most injurious misapprehension, from mere considerations of a chemical character.

Chemically pure acetic acid is a highly corrosive, pungent, colourless body, liquid at a temperature equal to, or above the mean temperature of this climate, but congealing to a crystalline solid during cold weather; from this latter circumstance the term *glacial acetic acid* has been applied to it. Such is the chemical standard, and the slightest consideration will prove that such a compound is totally unadapted to any dietetic purpose.

By diluting this real, absolute, or glacial acid with water, it can be tempered down to a degree of strength, admitting of its employment for all culinary purposes; but still it is by no means so agreeable as other specimens of acetic acid, and far less pure in a chemical sense.

Sources of Acetic Acid.—There are several sources of acetic acid; the most usual and most natural source is wine, beer, indeed any alcoholic liquid, under the influence of what chemists denominate the acetous fermentation. Acetic acid may also be obtained from the fermentation of saccharine solutions; but, strictly speaking, this source is also alcoholic, seeing that the latter derivative is a necessary antecedent to the production of acetic acid. By two, or perhaps more, specific courses of treatment, acetic acid may be developed from a mere admixture of alcohol and water; these cases do not involve the occurrence of acetous fermentation, and are too purely chemical in their principles for specific consideration here. The specific point to which I wish to draw the reader's attention is this:—In proportion as the alcoholic source from which the production of acetic acid is effected is pure, so will the acetic acid itself be pure. Thus, if it be the result of a chemical treatment performed on a mixture of alcohol and water, then the result will be a compound of mere acetic acid and water; but if the acid be obtained by the acetous fermentation of beer, cider, wine, &c., then will it be more or less contaminated with matter peculiar respectively to these various sources. Thus, not only do specimens of acetic acid (vinegar) differ according as they are obtained from cider, beer, and wine; but they differ also for every variety of cider, beer, and wine,—the difference in all these cases being wholly referable to the presence of bodies which, relatively to the chemical standard of acetic acid, must be termed impurities.

Distilled Vinegar.—When acetic acid, from whatever source obtained, is subjected to distillation, the kind of separative agency effected by distillation in any case is accomplished; that is to say, the volatile matters pass over, or are distilled, and the non-volatile matters, whatever they may be, remain behind. Amongst the former, and indeed constituting the chief of them, are colouring vegetable extractive, and certain fixed salts. The acetic acid which passes over, or is distilled, is therefore colourless, but by no means chemically pure, even though water, for the sake of convenience, be not assumed to belong to the category of impurities. The distilled acetic acid, or *distilled vinegar*, though colourless, will still hold in combination certain odorous deviatives, each one peculiar to the source from which the acid has been distilled; and each one, therefore, to be strictly regarded as an impurity; still, of course, having reference to the chemical standard of acetic acid.

Pyroligneous Acid.—When woody matter is subjected to destructive distillation, numerous volatile products distil over, and charcoal remains in the retort; of the former acetic acid constitutes an important constituent. By adequate chemical means, acetic acid from this source may be separated from all collateral matters, and rendered equally pure with acetic acid from any other source. When thus purified, there is of course no reason warranting its designation by any other name than acetic acid; still, however, even when thus rendered completely pure, the term pyroligneous acid is applied to it,—and this term the reader will perceive to be indicative of the fact, that it is an acid prepared from wood by the agency of fire. Considerable misapprehension appears to have obtained in respect of pyroligneous acid, even amongst the members of the recent parliamentary committee on food adulterations. Whilst the subject of vinegar was discussed before that committee, various questions were proposed relative to the substitution of pyroligneous acid for acetic acid, thus leading to the impression that pyroligneous acid was something intrinsically, and chemically, different from acetic acid, whereas, as we have seen, no such difference exists.

Brown or coloured English Vinegar.—By far the larger portion of acetic acid (vinegar) used in this country for dietetic purposes is a coloured compound specially prepared from fermented wort, and flavoured with raisins, &c., to render it agreeable to the palate. In addition to the ordinary results of this treatment, a small percentage of oil of vitriol is permitted by the legislature. The addition is said to be made with the intention of enabling the vinegar to keep better than it otherwise would; this may be so, but the oil of vitriol, by its intense sourness, adds to the pungency of the vinegar.

From a consideration of the facts which have been just set forth, the conclusion is irresistible, that the chemical standard of acetic acid can with no propriety or justice be adopted, as the basis of any legislative enactments having reference to vinegar in a dietetic sense. Chemically speaking, the most impure vinegars are those which are the most agreeable to the palate. For the manufacture of certain kinds of pickles, such as mushrooms, onions, and cauliflower, in either of which colour would be disadvantageous, colourless or distilled vinegar is an advantage; but for all other dietetic purposes, coloured or impure vinegar is preferable.

Arriving, lastly, at a fair legislative or commercial standard for vinegar, any departure from which to be considered an adulteration, let us now see by what limits an act of parliament or other legislative injunction should be restrained. Firstly, care should be exercised lest vinegar, from whatever source obtained, be impregnated by metallic bodies, more especially by soluble compounds of lead and copper. Provision also should be made for restraining the percentage amount of oil of vitriol within the proportions already conceded to be innocuous. Beyond these limits, it does not seem just or expedient that legislative interference should go. Questions of preference as regards mere flavour may be safely left to the decision of consumers; and questions of strength, involving the percentage amount of real acetic acid in any given sample, will soon fall into order by the operation of the laws of profit and loss.

Chemical Examination of Acetic Acid for Strength.—This involves an operation of more difficulty than is usually requisite in determining the strength of other acids. Specific gravity affords indications very wide of the truth indeed, because of the slight deviation between the specific gravity of pure water and pure acetic acid. The only certain way of ascertaining the strength of acetic acid consists in learning the amount of its saturating power; or, in other words, in learning the quantity of any given base it can dissolve. Generally the basic substance employed for this purpose is lime; and carbonate of lime, in the physical condition of white statuary marble, is usually the substance had recourse to. The greater the amount of real acetic acid per cent. any commercial sample contains, the more lime will a given quantity dissolve, and the greater will consequently be the loss of a piece of marble of previously known weight, after immersion in the commercial sample, until the latter is fully saturated. I need not comment on the necessity, when performing this experiment, of being assured that the specimen under analysis contains no other acid than the acetic. If, for instance, the specimen were to contain oil of vitriol (sulphuric acid), the latter would dissolve a portion of lime, commensurate with its own amount, and would import an error into the calculation.

Determination of Oil of Vitriol.—Sulphuric acid, or oil of vitriol, is easy of detection wherever it occurs. The property which it has of forming a white precipitate, insoluble in nitric acid, usually furnishes a sufficiently characteristic feature. If evidence still more rigid be desired, it may readily be obtained by mixing the insoluble white precipitate with powdered charcoal, heating the mixture to whiteness, adding hydrochloric acid to the result contained in a test-tube, and then inserting into the latter a slip of bibulous paper moistened with solution of acetate of lead. If the paper be tinged black, sulphuretted hydrogen must have been evolved; which sulphuretted hydrogen must be attributable to the presence of a sulphide. This, in its turn, must have been the product of a sulphate, and a sulphate determined under the conditions of the experiment necessarily presupposes the original existence of sulphuric acid (oil of vitriol). Inasmuch, too, as the amount of a sulphate (of baryta) is commensurate with the amount of sulphuric acid, the quantity of the latter originally present is directly inferred from a weighed estimation of the amount of the former. This operation, however, presents a case of chemical analysis,—one that will rarely be undertaken except by the professed chemist. Instead of a soluble salt of baryta, acetate of lead may frequently be employed with advantage to determine the presence of, and to separate, sulphuric from acetic acid. This process is peculiarly applicable to the case of brown or coloured vinegar, which, on account of the quantity of vegetable matter present, sometimes renders the application of barytic salts embarrassing. Acetate of lead solution, when added to acetic acid, holding oil of vitriol, not only precipitates the latter, but most of the vegetable matter also.

If, therefore, the compound precipitate be collected, washed, and incinerated in a porcelain crucible, all the vegetable matter will be burned away, and white sulphate of lead will remain. If the process of incineration be performed in a closed crucible, the sulphate of lead will be decomposed into sulphide of that metal, mixed with charcoal,—a mixture which evolves sulphuretted hydrogen when treated warm, with a little hydrochloric, or, still better, nitro-hydrochloric acid. This gas may be tested by bibulous paper, moistened with acetate of lead, as already described; and the resulting blackness of tint, if any, will be of course characteristic of sulphuric acid originally present.

Detection of Copper.—This metal, when present in vinegar, is detected by the same tests as those already mentioned, when treating of copper entering as a contamination into pickles and preserves.

Arsenic in Vinegar.—Oil of vitriol I have already stated to be present in many varieties of commercial vinegar; and inasmuch as oil of vitriol frequently contains arsenic, there are some grounds for the statement that arsenic is occasionally present in vinegar. When we come, however, to reflect on the comparatively small amount of oil of vitriol present in vinegar even in extreme cases of admixture, and on the small quantity of arsenic entering as a contamination into oil of vitriol, it will be seen that the reports concerning the presence of arsenic in vinegar are unnecessarily overstated. In point of fact, the alarm which has arisen on this score need not have existed; it was the result of a popular clamour, based upon the mere word of terror—*arsenic;* and furnishes an illustration of the mistakes into which a populace can fall when led astray by mere terms without due limitations of their significance.

Lead.—This metal readily dissolves in acetic acid, with which it may come in contact; it is, therefore, sometimes found in vinegar as a contamination. If vinegar yields a black tint or a black precipitate when treated with hydrosulphuric acid, the presence of some calcigenous metal is indicated. If the metal in question be not copper, the probability arises that it is lead. If the addition of a soluble sulphate to another portion of the vinegar yield a white precipitate, the probabilities in favour of lead are almost confirmed; but there is no absolute confirmation of the point short of the process of evaporating the suspected vinegar to dryness, incinerating the residue, and obtaining the lead by processes obvious to the chemist, but beyond the competence of ordinary non-chemical operators.

Adulterations of Coffee.—Perhaps the subject of adulterated viands, considered generally, would not have been prominently brought before the notice of the public as we find it, had not the sophistication of coffee furnished the starting-point. The chicory question furnishes one of the numerous instances which might be adduced of the pressure which considerations of profit and loss can exercise, though considerations of a far higher moral weight—considerations involving the health and physical well-being of a people—would have been passed unnoticed. Although evidence has been forthcoming inculpatory of the injurious effects of chicory sanitarily considered, that evidence, to say the least of it, is weak and unsatisfactory, viewed by the light of unprejudiced experience. Chicory cannot be said, I believe, to be more deleterious than coffee, taken dose for dose: coffee, indeed, is the more active substance of the two; its effects on certain delicate constitutions are so strongly manifested, that, without a violation of language, it may almost be designated a weak poison. To raise a special outcry against chicory because of its injurious character on the constitution, is simply absurd; nor would it ever have been raised, had not the customs receipts on coffee experienced a decrease incompatible with the necessities of the Chancellor of the

Exchequer. Unquestionably some palates like chicory, others detest it. The philosophic, and indeed the only practical, way of dealing with chicory would be to permit its sale—of course, seeing that it is not injurious—but not to permit its sale when mixed with coffee, except the percentage quantity of the mixture be strictly defined. At present the sale of chicory-coffee mixture is regulated on a very objectionable basis. If a purchaser demand to be supplied with coffee, the retailer may deliver a mixture of chicory and coffee, provided a label expressive of such mixture be attached to the parcel. If the purchaser, however, ask for pure coffee, or coffee unmixed with chicory, then it is incumbent on the retailer to heed the request. All this is very objectionable; it is an example of the ill-effects of legislating in detail. If, instead of legislating in the specific matter of coffee, some scheme had been adopted of generalizing on adulterations—a scheme based on some principle which should apply to every case of adulteration whatever—much confusion would have been avoided, and public morality, as well as public hygiene, would have been promoted. The present regulations affecting the sale of mixtures of coffee and chicory are very unjust to the purchaser, and provocative of deceit to the retail dealer. Not only is the latter allowed to take advantage of the purchaser who does not think it necessary to qualify the word coffee by the expletive "*pure*," but provided the chicory-coffee sold be enveloped in a paper duly labelled, the dealer may raise the percentage amount of chicory as high as he pleases; he is under no legal restraint whatever.

In order to illustrate this part of the subject, it may be well to quote a portion of the evidence of Mr. G. Phillips of the Excise, when examined in 1855 before Mr. Scholefield's select committee.

Mr. Villiers (*Question* 2197). "Upon what principle is it, that if people ask for anything so distinct as coffee, it is sanctioned by the Excise that traders may sell something so different, as these mixtures?"—*Ans.* "For this reason: if you trace the history of chicory, you will find that prior to the year 1832 we had heard nothing of the use of chicory in this country; it had been gradually going on for some years, but by sensible degrees, till in the year 1832 it had arrived at such a height that the Board proceeded against a trader in Liverpool. This proceeding was stopped by an order of the Treasury. Then there was a Treasury order not allowing the mixture of chicory with coffee. That went on till the year 1840, when steps were again taken to prosecute a party, but were annulled by the Treasury by an order of the 31st of August. From that period we have gone on allowing persons, till recently, to put chicory into coffee. Now the regulation I have named is, that they must state that it is a mixture. I can only account for the fact that when a person goes into a shop and asks for coffee, he is supplied with chicory and coffee by the practice of the trade."

(*Quest.* 2198). "Surely you would never get any ordinary consumer of coffee to consent to such a proposition as that; does the public know this rule of the trade—is it stuck up in the window that if they ask for coffee they will get chicory with it?"—*Ans.* "No; we allow this indulgence to the trade if they comply with our regulations."

Perhaps the worst part of these loosely-defined, exceptional legislative measures, is the encouragement they hold out to deception and hypocrisy, lowering the standard of honest trade down to the level of unfair dealing, laying sap to the moral sense of the retailer, and mystifying, to his own prejudice, the consumer.

Shortly after the chicory-mixing practice became adopted in this country, certain contemplative men began to reflect on the impermeability of tin-plate canisters. Everybody knows how desirable it is to retain the aroma in coffee. The best plan of accomplishing this consists in roasting the coffee when wanted, but the practice hardly accords with our domestic habits and cuisine. The next best plan consists, perhaps, in hermetically soldering the coffee in tin-plate cases; accordingly the canister project was based upon the principles of true philosophy—the idea was attractive, its practical application easy: here are sound reasons, therefore, in favour of the canister scheme. But its denouement was heralded by other recommendations. Curiously enough, the exaltation of chicory was contemporaneous with decadence of alcohol—canister coffee was the agent by force of which total abstinence aspired to domination. Evil-minded people, who, knowing that the tin-plate costs money, marvelled not a little that a pound of coffee in tin should be sold for less than an equal weight of coffee in paper, were told that they knew not the power or the extent of Christian benevolence in well-ordered minds. The coffee canisters, people were made to understand, originated in no sordid motive of vulgar gain, but sprang, Minerva-like, from the teeming brain of spirit-hating abstainers—men who so little cared for profits, that they were content to live by the loss. But I seriously doubt whether tin-canisters, if they could speak, would not proclaim themselves innocent of protecting the virtues of any one sample of pure coffee. They are, in sober earnest, mere chicory traps; and frequently they are filled in accordance with a nicely-calculated scheme of deception,—chicory almost pure at the bottom, and coffee almost pure at the top.

Discovery of Chicory.—Some years ago certain gentlemen testified, before a committee of the Lower House, that there were no known and certain means of distinguishing chicory, in powder or grain, from coffee in a similar state of aggregation. Surely these witnesses must have lost their sense of smell, for anything more distinctive than the odour of chicory compared with that of coffee cannot be well imagined. Besides the indications of odour, there are several methods of discovering the presence of chicory. It is somewhat sweet to the taste, and gives the impression of something gritty when bitten; coffee manifests neither of these properties. Chicory, too, when thrown into water, even though the water be cold, imparts to the latter almost immediately a deep tint, which coffee does not. These indications are usually sufficient; but, if necessary, a last appeal may be made to the microscope, the indications of which are infallible.

As to the relative amount of coffee and chicory in the mixed compound, it varies within very wide limits. Mr. Phillips, in his evidence given before Mr. Scholefield's committee, testified, as the result of his experience, and of the communications made to him by grocers, that about one-eighth chicory was the best proportion. This percentage, however, is often exceeded; some palates are, doubtless, partial to the taste of chicory; indeed, in certain districts of England, especially near Manchester, chicory unmixed with coffee is infused, and made to take the place of coffee as a dietetic drink.

I believe the chief cause wherefore chicory retains its appreciation by a large section of the public is, because of the colour and coarse extractive it imparts to an infusion of coffee. Every person conversant with physiology knows how comparatively rare is that combination of a delicate sense of taste and of smell, to which the term "palate," in its gastronomic sense, is applicable. As a rule, this power of appreciating distinctive flavours and aromas only exists in that section of a society to which the term intellectual, in contradistinction to manual, may be applied. A brewer's drayman would thrust a glass of Johannisberger from him in contempt, though enamoured of his own heavy drink. He is but a type of a class; and his preference for beer is a type of his preferences, from one end to the other, of the dietetic scale. He would prefer the black coarse infusion of chicory and coffee to the purest light-coloured infusion of Mocha, however redolent of delightful bouquet. Nor does it much signify if the chicory be impure, so long as a certain dark tint and rough flavour be preserved. As regards the adulterations of chicory, they are numerous, and often disgusting. Mr. Phillips discovered in several samples of chicory which came under his notice, beans, rye, oats (roasted and ground), caramel or burnt sugar, red oxide of iron, orange berries;—nothing very disgusting in these things:—baked and powdered horse-liver is more objectionable, and decayed wood reduced to powder is unattractive in all its varieties,—*especially* repulsive does it become when the wood-powder is the product of grinding exhumed and decayed coffin-lids. The baked-liver adulteration has, I believe, been well attested; the latter, I am bound to say, is more apocryphal.

Seeing that chicory is not injurious, and that the taste of people respecting it is divided—some persons holding it to be an improvement to coffee, whilst others regard it as altogether hateful—the straightforward and rational method of dealing with the matter would consist in selling chicory as chicory, and coffee as coffee. This would be inconvenient to the poor, we are told, who are enamoured of chicory, and who cannot mix the two so well as the grocer, who grinds the two together in a mill; the poor cannot afford to have mills, only the rich, &c. &c. But surely it was not philanthropy that suggested the fashioning of chicory into the appearance of coffee-berries: a patent was actually taken out for that purpose some years ago!

Malt Liquors.—According to the investigations of Dr. Normandy, and other chemists who have given much attention to the examination of malt liquors, there is very little draught porter sold in London as it comes from the brewers. "Beer," remarks Dr. Normandy, "is a liquid which is very largely adulterated; but I must say, as far as my knowledge goes, not in one single instance by the brewer. The adulteration takes place at the publican's, and to such an extent that there is actually a difference of fifty per cent. sometimes in the quantity of the alcohol which the same beer contains when it comes from the brewery, and when it is bought from the publican. I am speaking of that with very great certainty, because I have purchased porter from a brewer, and I have purchased the same beer of a publican where the beer is retailed, and I was surprised to find that the quantity of alcohol was so enormously different. The beer is so greatly adulterated, that I always purchase the beer I consume from the brewery, and I have done that for several years past. Lately I was out of beer, and I sent to a public-house for some, but I could not drink it; it was perfectly vapid, and nauseously sweet. The substances which can be detected as adulterating substances are only two, namely, common salt, which is used to a much more considerable extent than it should be, probably merely for increasing the thirst of the customer; and sulphate of iron, by which I once suffered pretty severely. I was at Bermondsey, coming from a tanning factory; it was in the heat of summer, and I stepped into a public-house to take a glass of porter. Very soon after I was seized with violent cholic and vomiting, and felt exceedingly uncomfortable; I drove home, however, and the symptoms disappeared rapidly. The next day I returned to the same place with a bottle, and bought half-a-pint of beer at the same public-house, when I found the presence of sulphate of iron; and I attributed, of course, to the presence of that poison my indisposition."*

Adulteration may be designated as an unspoken falsehood; it is attended by all the evils inseparable from verbal falsehood, and many peculiar to itself. As one falsehood requires others to give it verisimilitude, so does one act of adulteration. The case of porter-adulteration forcibly illustrates this point. The retail dealer obtains his porter from the brewer according to a normal standard; one that is never departed from at the manufactory. The retailer, instead of retailing the porter as he gets it, begins by adding water. He will say there is no great harm in that; he will argue that porter as originally brewed would be injuriously strong for his customers; he will aver that the diluted portion is the strongest he can afford to sell for the money. But in adding water he has violated—unconsciously perhaps, but he still *has* violated—the immutable laws of justice and morality: he has committed a lie; and a lie committed, like one spoken, requires others to support it. What, then, does the publican do? By the incorporation of nostrums with the diluted porter, he creates a false idea of strength; he adds sulphate of iron to impart an inky colour; treacle, sugar, or liquorice, to give both colour and body; salt to increase thirst; and, worse than all, he strives to deceive the palate of his customers, and to impart a false notion of alcohol, by capsicum and the deadly *cocculus indicus!*

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* Evidence before Mr. Scholefield's Committee, 1855.

Of course it is not assumed, in the preceding remarks, that the whole of the ingredients mentioned find their way into the whole of the metropolitan porter,—an assertion of that kind would be far too sweeping and indiscriminate; unquestionably, however, they are very generally employed. Neither is it assumed that the different materials of porter-adulteration are added *seriatim*, beginning with water, as described; they are added at once, but the sequence indicated is the sequence of causation. Were it not for the water, none of the remaining additions would be necessary.

"For the purpose of imparting strength," says Dr. Normandy, in his evidence before Mr. Scholefield's committee, "they add to it a certain quantity of foots-sugar,* because, by diluting the beer, they have rendered it less sweet, and therefore a little sugar is added. By the addition of water not only have they diminished its sweetness, but they have also diminished its colour; and then they put into it a little liquor ammoniæ, or spirit of hartshorn, which has the property of darkening beer—so much so, that if you add a little ammonia to pale ale, it will become the colour of porter. Instead of hops, extract of gentian is used. Gentian is not a deleterious substance; it is introduced merely because the beer has been diluted, and it is no longer so bitter as it should be, and therefore a little extract of gentian is introduced."

Speaking generally, the assertion may be truthfully advanced, that the adulteration of malt liquors is confined in this country almost exclusively to porter; ale does not afford equal facilities to the adulterator. Firstly, in ale there is no tint of darkness to be maintained; secondly, it is more fresh to the palate, and consequently agents of adulteration cannot be so well applied as in the case of porter. Nevertheless, ales present an opportunity for the introduction of extraneous bitters, and quassia and gentian are said to be employed for the purpose; but the apprehensions prevalent some few years ago relative to the employment of strychnia had never, I am disposed to believe, a just foundation.

Detection of the Materials employed for the Adulteration of Beer.—Sulphate of iron, common salt, and indeed all the mineral substances employed for the adulteration of beer, can be readily detected by obvious chemical methods. Nux vomica, also, and its alkaloid, admit of ready detection; but neither by the microscope, nor by chemistry, nor by any other known method, can the presence of *cocculus indicus* be determined.

Legislative or Normal Standard of Malt Liquors.—The confusion which has arisen for want of a legislative standard of comparison in relation to malt liquors, is aptly illustrated by the following remarks of Lord Claude Hamilton, when speaking of the previous use of the words adulteration and contamination by Dr. Normandy:—"You make use of the word 'adulteration,' but the man who makes porter does not promise to make it of any particular ingredients, does he? He makes a beverage, and he offers it for your acceptance if you choose to drink. Adulteration, I take it, means this: the addition of a substance which does not impart to the article adulterated any quality whatever. For example, I do not call the mixing of cotton with wool, or with silk, an adulteration, because the result is an article which looks nearly as well, and which partakes of the qualities of the fabric which is made exclusively of wool or of silk. But if the article is sold as pure wool or as pure silk, it is not a case of adulteration; it is a case of fraud, according to my vocabulary. I think the fault, in that case, lies at the door of the vendor, but not at the door of the maker. In the same way, if what I understand by the manufacture of beer is the making of a certain beverage containing hops, and a certain amount of alcohol, a certain well-known compound; if you introduce water and *cocculus indicus*, and foots-sugar for the purpose of sweetening, and liquor ammoniæ for the purpose of browning, it is a case of both adulteration and fraud." Differences of opinion of this kind, relative to the true signification of the word "adulteration," will not cease until the latter has been defined for legislative purposes. If the legislature see fit to consider it to be a deviation from a standard, many difficulties would be overcome. The legislative standard for malt liquors should involve, firstly, the presence of a determinate amount of alcohol. If the greater sobriety of beer-drinkers be a consummation to be attempted, as no rational person disputes, it should not be attempted through the intervention of a fraud. I am disposed to believe that the most efficient means of counteracting the tendency to drunkenness, unfortunately so prevalent in this country, would be the importation of light wines. I believe alcoholic drinks, taken within limits of temperance, to be a good and rational means of developing the mental and bodily powers of man. I cannot join in the gratulations of those who now so enthusiastically enjoy the blessings, as they say, of total abstinence. I have seen something of the operation of this enthusiasm, not only in England but in Ireland, more especially in the native city of the originator of the movement; and, even taking the low ground of argument, that a pledged abstainer is a drunkard saved, I find it impossible to accede to that proposition in all its universality. According to my experience, a pledged abstainer is too frequently a man who drinks in secret, thus adding hypocrisy to the other sin.

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* This term is applied to the sugar in the lower part of a cask, and into which the portion of molasses originally contained in the upper part has gravitated.

Tea and its Adulterations.—The popular, and to some extent the commercial classification of tea is into green and black. This distinction is supposed to be due to a distinction between the plants yielding the two varieties; but still there is little reason for doubting that a portion, at least, of the green tea used is the produce of black tea-plants, the only distinction between the two results being in the manner of preparation.

Connoisseurs in tea will have remarked the almost total disappearance within the last few years of those finely-bloomed, lustrous green teas, which we were accustomed to see ornamentally displayed in shop-windows. Since the nature of the contaminations effected in tea, and more especially green tea, has been known and understood, the objectionable practice has already begun to decline. Between the natural colour of green tea and black tea, there is much less difference than the public is accustomed to suspect. Black tea is neither characterized by extreme blackness, nor green tea by extreme greenness; so that wherever either of these appearances is observed, contamination may be suspected.

Formerly, the opinion was entertained that green tea owed its greenness to a cupreous impregnation. This opinion is unfounded: iron, not copper, is the metal on which the leaves are dried. Moreover, the bloom of green tea is only superficial; between it and the greenness of cupreous pickles, there is all the difference between dyeing and surface painting. The operation of tea-glazing was first brought under the notice of the public in 1844, by Mr. R. Warington. Two samples of green and black tea were brought to him by an excise officer, who had made a preliminary seizure in the neighbourhood of Kennington. He wished to know of Mr. Warington whether they were genuine teas; and he was requested to obtain further information as to the identification of the samples with the bulk of the teas. The excise officer, however, never called again. It so happened, however, that the samples of tea in question lay before a window, and one day Mr. Warington was much struck with the varying tints on the surface of the green tea when viewed in sunshine. He examined the tea microscopically, and found it to be enveloped in a colouring material. Subsequent chemical examination demonstrated the colouring material to be composed of Prussian blue, turmeric, and a white substance which appeared to be a mixture of soap-stone, or steatite, with sulphate of lime. In the course of certain inquiries made by Mr. Warington on this subject, he was asked whether he had examined "*unglazed*" tea. The term was new to him; he expressed his surprise, and was then informed that two kinds of tea, as concerns the peculiarity of glaze, were known to the trade, *i.e.* glazed and unglazed tea. A sample of the latter had no green colour at all—it was of a dull slate colour: it contained no turmeric, and a very small quantity of Prussian blue; but there was still a small quantity of sulphate of lime upon the surface.

Passing on to a contemplation of the results of the kind of contamination just described, we shall find them to be inappreciable, directly considered; and that the major evil which they are competent to exercise is traceable to the facility they give to ulterior deterioration. If real tea can be faced, so can unreal,—in this consists the major evil; and here again, in the matter of tea, the difficulty, or rather the impossibility, is recognized of setting universal bounds to a contamination. If there be not such an existence as abstract truth, surely there is no such thing as an abstract evil. In both, the principle of action may be dormant; but it is nevertheless there, ever ready to display its vigour when the proper opportunity occurs.

The ingenious Chinese have turned the operation of glazing tea to some account in the fabrication of a material, denominated by the people of the Celestial Empire themselves "*lie-tea.*" The term lie-tea is sufficiently expressive of the fraud. To call the material in question, tea, is a veritable fraud; in short, "*a-lie.*" May we not say that the Chinese display greater reverence for truth and propriety than ourselves? If our food-adulterators were boldly to tell us that the adulteration *was* an adulteration—"*a lie,*" would not this open confession more than half protect us against the consequences? These lie-teas contain about fifty per cent. of earthy matter; they hold a parallelism with the result of that estimable patent process already referred to, for the transmutation of powdered chicory into coffee-beans. Rice-flour, tea-dust, gum, sweeping of the floors of tea-warehouses, mixed with from thirty-seven to forty per cent. of earthy matter,—the whole ground so as to imitate tea, and elegantly faced,—make up the spurious material to which the denomination "*lie-tea*" is given. According to the testimony of Mr. Warington, the cost of lie-tea in China varies from 8d. to 1s. per pound; it cannot come into England until it has paid the duty of 2s. 1d. per pound; and it would probably be sold to the poor, or bad judges of tea, at 3s. 6d. per pound.

Determination of Lie-tea.—The means of determining the identity of lie-tea are so easy and obvious, that none except the incautious or the very ignorant can be deceived.

If hot water be poured upon it, instead of unfolding and displaying the form of a leaf, after the manner of real tea, it falls to pieces at once, thus furnishing a very obvious test. If, again, lie-tea be incinerated in a crucible of porcelain or platinum, or, indeed, even in an iron spoon, the enormous quantity of earthy matter which it contains will be found as a residue.

The processes of tea adulteration to which the reader's attention has been already directed take place, as we have seen, in China; practices, however, equally nefarious have been followed in England. One of the most remarkable was followed in a factory near Manchester, where exhausted tea-leaves were dressed and manufactured in such a manner, that they ultimately passed muster with the incautious as tea. That particular manufactory, it is to be assumed, did not prove remunerative; at any rate, it is not at this time in existence.

Before concluding the subject of tea, I may remark, that being myself very much addicted to tea, which I have taken, so long as I can remember, without the usual additions of milk and sugar, my palate is somewhat critical in respect of the infusion. The best tea I can find is that imported by the Messrs. Horniman: its dull, unattractive appearance manifests it to be what it professes—tea which has been subjected to no kind of extraneous embellishment whatever—a manifestation which its delicious flavour sufficiently confirms.

Cocoa and Chocolate.—The beans* of the *Theobroma cacao* are well known to be the raw material from which the dietetic articles, ground cocoa and chocolate, are made. Firstly the beans are torrefied, or roasted after the manner of coffee; they are then ground, and sometimes made into a drink without further preparation; though this is rare. Chocolate is necessarily a compound preparation: it professes to be such; but most of the ground material sold under the name of cocoa is compound also. Notwithstanding the agreeable taste of cocoa, and the elements of nutrition which it contains, there are great difficulties in the way of reducing cocoa to the condition of a beverage. It requires to be boiled, or rather stewed, for many hours, in order that the ground particles of the cocoa-nut shall become tender. This quality is inconvenient, and to the extent of its inconvenience objectionable; hence has arisen a sort of necessity for some kinds of admixture. The word chocolate, as originally understood, was supposed to apply to a paste composed of the cocoa-bean, intimately ground with sugar and formed into a cake. Rarely, however, at any time, or in any country, was chocolate so simple in its composition as this. More frequently (in addition to sugar), spice, starch or flour, and other materials, were added. In England, and at present, this is universally the case; and, indeed, the addition of starch is almost a necessity, so long as chocolate is prepared as a *drink*. The Spaniards, it should be understood, never *drink* chocolate; they boil it to the consistence of a moderately thick paste—so thick that it can be removed from the cup and eaten on the extremity of a rusk or biscuit. This, in point of fact, is the usual way of preparing chocolate in Spain. It may be remarked, too, of Spanish chocolate, that milk is not the diluent liquid, but water. In France and Germany chocolate is usually prepared thicker than with us, but not so thick as in Spain; and milk is the diluent liquid employed. In England it is the custom to prepare chocolate as a *drink*; so that were not starchy matter a large constituent of the chocolate, there would result, notwithstanding any amount of melting and boiling, an unpleasant-looking sediment.

Between chocolate, so called, and the various kinds of mixed or prepared cocoa, the distinction is altogether conventional. Most of the articles of admixture have reference to the natural insolubility of the tissue of the cocoa, though some are employed to heighten colour and increase weight; of this kind are red oxide of iron (iron rust) and red-lead. It should be remarked, however, that the latter highly poisonous substance, though reputed to be a frequent addition to coffee and chocolate, has never been found in either by Dr. Normandy, a gentleman who has devoted much attention to the subject of food-adulterations.

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* Popularly so called—not botanically.

Looking dispassionately at the subject of cocoa and chocolate, I think the conclusion will necessarily be arrived at that the outcry of adulteration raised against them has but little solid foundation. By this I would be understood to admit that the article sold as cocoa is seldom or never the unmixed result of grinding the cocoa-bean, but to assert that by the admixture of starch and sugar it is rendered more fit for dietetic purposes. When Parliament legislates on this article of food, it would probably suffice to make provision against the presence in cocoa or chocolate of mineral bodies.

Spirituous Liquors.—Under the general denomination *spirituous liquors*, are comprehended those various mixtures of alcohol with water,—in some cases colouring, and in all cases odoriferous matters,—which constitute the liquids known as brandy, whisky, gin, rum, arrack, &c.

Frequently the medical man will be asked the question whether gin, brandy, rum, &c., is the purest spirit. The question is totally unmeaning and unintelligible, except some previous legislative standard of purity be agreed upon. With this assumption, I suppose the chemical standard of pure alcohol, or the excise standard of proof-spirit, must be adopted; in which case the purest spirit will be synonymous with the strongest spirit. Such a standard, however, is practically false and inefficient: pure alcohol, like pure water, is disagreeable to the palate; the flavour innate to it requires to be covered by the addition or incorporation of other flavouring matters, the presence of which latter constitutes the essential distinction between alcohol and potable spirit; and according as the foreign constituent differs as to nature, so will the resulting spirit be brandy, gin, rum, &c. Guided by this principle, the chemist has it in his power to manufacture many potable spirits from alcohol, by the addition of the necessary flavouring agents.

Since the failure of the vine-crop, alcohol, the result of fermented malt, has been largely imported into France from England as a basis for the manufacture of brandy; and if the alcohol produced from the fermentation of malt could be *absolutely* deprived of its foreign odorous matters, which, I believe, it cannot, there is no reason wherefore brandy from this source should not be equal in quality to brandy drawn from fermented grapes. It so happens, then, that much of the brandy now imported from France is not similar to, but identical with, the brandy manufactured here, and known as British.

The distinction necessary to be drawn between pure spirit,—understanding the word purity in its chemical sense,—and palatable spirit, is well illustrated by the operation of whisky manufacture. Some time since a most elaborate and a very beautiful method of distillation was discovered by an engineer named Coffey. The apparatus was adopted by some Irish manufacturers of whisky. I saw it in operation at Cork, in the year 1848, and was delighted with it. Since that period, however, the Coffey apparatus has been abandoned by the greater number of whisky manufacturers, because, to use their expression, it destroyed the flavour of the spirit; but, in the strict language of chemistry, because it yielded a spirit too pure—in a chemical sense, too nearly approaching the condition of alcohol, or alcohol and water—to suit the public taste. Whisky, in point of fact, is alcohol plus certain odorous foreign matters. What the whole of the flavouring agents may be which confer on whisky its peculiar odour and taste, is not known.

They admit, however, of being developed under conditions where they would be little suspected; a curious instance of which lately came under my notice, and in the following manner:—Taking into consideration the uses to which alcohol may be applied in the arts and manufactures, an act, known as the Methylated Spirit Act, was passed last year, legalizing the sale, under certain protective conditions, of alcohol, or rather alcohol and water, mixed with a certain volume of wood-naphtha, or methylic alcohol.

This admixture does not interfere with the use of the spirit in the manufacture of varnishes for the operation of French polishing; for the purposes to which it is applied by hatters, and many other direct applications. Ether, too, may be made from it nearly, but I think not quite, pure, and also chloroform; but it is assumed that the percentage of wood-naphtha added, renders the spirit so nauseous that no person, not even the veriest drunkard, would venture upon a dram of it. About six months since, I prepared some chloroform from this methylated spirit, by the usual process of mixture with chloride of lime and distillation. After drawing off all the chloroform which had been generated, I was much surprised, on raising the temperature, to find evolved an alcoholic mixture which had all the characteristics of weak whisky: so closely did it resemble whisky-and-water as to deceive all who tasted it.

During the progress of Mr. Scholefield's committee, much was stated respecting the adulteration of gin; and much confusion resulted for want of a definition of what should constitute adulteration in a legislative sense. The process of gin-adulteration appears to be this: the retail dealer begins by adding water, which addition of course lowers the alcoholic strength of the gin. This lowering of strength necessitates further solicitude. Capsicums are added to impart a pungency suggestive of alcohol; cocculus indicus for the purpose of imparting the quality of narcotism; and a mixture of oil of vitriol and oil of almonds for the purpose of giving a certain conventional appearance of beading. The fountain-spring of adulteration, therefore, is water. Were the real strength of the gin not lowered by this agent, the subsequent incorporation of other adulterating bodies would be unnecessary. Nevertheless, the morality of this addition of water found advocates to speak warmly in its favour!

Water.—Although in the limited space allotted to the subject of food-adulterations in the *Circle of the Sciences*, many special ingesta must necessarily remain undiscussed—it would be unpardonable to omit altogether a liquid which has so large a share in ministering to our vital necessities as water. Independently, too, of its intrinsic value, water has another claim to our consideration in this place. It conveys an illustration of the necessity which exists for distinguishing between the terms *purity* and *fitness*;—terms which, though held to be equivalent by many who have written and spoken much concerning food-adulterations, are really quite distinct; and when the distinction is not felt and recognized, misunderstanding necessarily follows. Perhaps I may take the assumption for granted, that most persons possess sufficient chemical knowledge to be aware that nature—by whose benevolence nothing is done injuriously or in vain,—though designing water to be a pabulum necessary to our very existence, furnishes the whole human race with not one specimen of pure water. In water absolutely pure, fish cannot live; and when taken into the stomach of man and other animals, it is flat and disagreeable,—nay, more, it is positively injurious. Again, not only is water, as we naturally find it, more or less impure, but the impurities differ to such an extent in mixture and degree, that perhaps no two samples of water, each taken from a different source, are exactly similar in chemical constitution. Surely these facts are significant. They not only show how little the idea of chemical purity can with propriety be adopted for any one dietetic solid or fluid; but they also show that, in respect of qualities and variations of impurity, the stomachs of animals are permitted a wide margin, still within the limits of innocuity.

Pure or Distilled Water.—Although no such fluid as pure water is found in all nature, we must not neglect it; we must accept it as the basis or standard of comparison for other varieties. Two methods exist of obtaining water absolutely pure: they are—distillation, with the precautions known to chemists; and artificial formation, by the combustion of oxygen and hydrogen gases. Of all natural waters, rain and snow-water approach most nearly to the condition of purity; they are far, however, from being absolutely pure, in the chemical sense of the word purity.

Popular Classification of Water Impurities.—The most obvious classification of the impurities found in water is into the volatile and non-volatile. By far the greater number belong to the latter category; hence, speaking generally, the amount of impurity which any sample of water contains may be determined by evaporating it to dryness, and weighing the amount of impurity left as a residue.

The crust which forms inside a tea-kettle furnishes at once a striking illustration of the fixed or non-volatile impurities which water contains. Every time the tea-kettle is boiled an amount of water is volatilised, and dissipated in the form of steam. If this steam were subsequently condensed it would result in distilled water. As for the non-volatile impurities, they necessarily remain; and inasmuch as every operation of boiling adds a little more, a crust eventually results, generally composed of carbonate of lime, and perhaps a little carbonate of magnesia, coloured somewhat by iron oxide, or organic matter—frequently both. Every person is conversant with the terms, hardness and softness, as used to indicate two opposite characteristics of water. The quality of hardness is referable to the presence of mineral and non-volatile substances, more especially carbonate and sulphate of lime; the quality of softness, conversely, is referable to the absence of the same,—whence it follows that pure or distilled water is softer than any natural variety. Although pure water be flat and disagreeable as a beverage, yet few persons who have not tried the experiment know how well-adapted pure water is for the making of tea and coffee, and for washing. The peculiar flat taste of distilled water is referable to the absence in it of dissolved atmospheric air. By allowing it to stand during a few days in an open vessel, and still more rapidly if agitated atmospheric air is absorbed, the agreeable freshness is conferred; hence, in our war-steamers, the process of distillation is had recourse to for the purpose of supplying the crew with potable water. Many natural varieties of water are so exceedingly hard—that is to say, they contain so great an amount of mineral constituents, especially lime, that they cannot well be employed for domestic purposes; hence some ready method of separating a portion of these mineral constituents becomes highly desirable.

Perhaps the process devised by Dr. Andrew Clarke is the best to this end. He separates lime by a process which will seem to all, except chemists, remarkably strange—*by the addition of more lime.* The philosophy of the operation is as follows:—The lime which hard-water contains is mostly carbonate of lime, held in solution by an excess of carbonic acid; hence, if we could take away all excess of the latter, carbonate of lime (chalk), no longer dissolved, would fall. Now quick-lime accomplishes this removal; hence the philosophy of Dr. Clarke's process. The property which hard-water possesses of curdling soap, instead of forming a smooth lather, furnishes a good test for hardness. The soap being dissolved in spirit of wine, a clear liquor results, a portion of which being added to the water under examination yields a curdiness, which is greater in amount as the water is more hard;—an experienced eye soon learns to recognize the degree of hardness. Of course the soap-test does not indicate the exact nature of the hardness-causing material; that indication can only be arrived at by an elaborate analysis.

Inasmuch as every natural variety of water is referable primarily to an atmospheric source, it follows that all the various foreign constituents of water, whether inorganic or organic, are derived from the substances wherewith the atmospheric water, after its fall, chances to come in contact. Long exposure to the air is a condition unfavourable to the solution in water of the maximum amount of inorganic matter, though it is a condition promoting the contamination of water by animal and vegetable bodies. Thus it is that well-water contains usually a greater percentage of mineral impurities than river-water; and, generally speaking, the degree of mineral impurity is greater as the well from which it is drawn is more deep.

Action of Water upon Lead.—Lead being a very poisonous metal, and one, nevertheless, much employed for the purpose of water-conduction, it is highly necessary to be aware of the circumstances under which it may, and may not, be used for that purpose. Fortunately, all the practical truths enabling us to arrive at a decision on this point are thoroughly made out. Water absolutely pure—that is to say, *protoxide of hydrogen*—chemically considered, holding nothing in solution—not even atmospheric air—appears to exercise no solvent action on lead; but only once let it dissolve atmospheric air, which, under all practical conditions, it is sure to do, and it corrodes lead with poisonous facility. For this reason no kind of water direct from the clouds—whether rain, snow, or hail-water—can be stored in or transmitted through lead, without such an amount of solution of that metal taking place that the water is rendered highly poisonous. For the most part, rain and well-water may be stored in leaden tanks or transmitted through leaden pipes with safety. Frequent exceptions to the rule, however, occur, so that the utmost caution should be exercised in adapting the metal lead for this purpose. By the addition of a minute portion of common salt, or, indeed, almost any soluble mineral substance, to rain-water, the property of lead solution vanishes.

Means of detecting Lead.—Water in which lead is dissolved may or may not have a sweetish astringent taste; but it will invariably strike a dark colour with hydrosulphuric acid, or solution of the same, if present in any considerable quantity. In order, however, that the test may be applied with the greatest chance of success, it is better not to test the water in bulk, but to concentrate the latter by evaporation, and subject the residue to the operation of testing. Hydrosulphuric acid, or its solution, is better for the preceding operation than hydrosulphate of ammonia, inasmuch as the latter would not only yield a black tint with lead, but also with iron. When, however, suspicion arises that so deleterious a material as lead is present in water, it is better to entrust the operation of testing to a professed chemist—I mean, of course, an analytical chemist. A gentleman, when giving evidence before Mr. Scholefield's select committee on adulterations, stated that English chemists and druggists were, as a class, almost ignorant of chemistry. He was not far wrong.

Conclusions.—With these remarks on water, I shall conclude the subject of food adulteration. The subject might be extended almost indefinitely, embracing each particular article of ingesta, solid and liquid. This I should not think desirable, even were space at my command. The evils of food adulteration are not so much to be abated by an elaborate review of each article of food and drink *seriatim*, as by the adoption of some comprehensive principle which shall involve the whole. On the one hand the public has been needlessly alarmed by statements of impurity based upon the consideration of a purely chemical standard; on the other, the processes of what must be called adulteration under the most liberal acception of the word, call for immediate legislative interference.

The legislature will have to begin by agreeing on normal standards for each of the ingesta, and tests by which departure from these standards may be readily ascertained. I entirely concur in the opinions expressed by Mr. Simon, the learned and indefatigable medical officer of the Board of Health, that the fixing of these normal standards should be delegated to the pathologist, or medical man, rather than to the chemist; and here at this stage alone can pathological opinions be advanced under circumstances of such freedom from bias as the case requires. What the great physician, Celsus, said long ago of medicine, that it was a conjectural art, is equally true at the present time. The symptoms indicative of the action of ingesta, whether of medicine or of food, on the human system, are veiled and distorted by the inscrutable operation of life. Seldom is it that reliable knowledge respecting them can be arrived at by the evidence of one given case. The safety of the pathologist lies in viewing the human constitution in the aggregate, and basing his conclusions on the resultant of a multitude of cases. By adopting this course the investigator will at least emancipate his judgment from the shackles of personal bias—an influence from which the best of us are not exempt, and which is the greatest enemy of truth in all cases where highly probable deductions take the place of absolute demonstrations.

When the legislature has taken counsel of the physiologist, and agreed upon normal standards of ingesta, then physiology should abandon the field, and chemistry, aided by the microscope, should step in, rigorously scrutinizing the compound ingesta, and denouncing every aberration from the standard already agreed upon by law. Physiological opinions directed towards any one specific case should ever be ruthlessly set aside: at this stage they will be frequently tainted by the poisonous bias of the retaining fee; and they will be always at such times advanced under conditions unfavourable to the development of truth.

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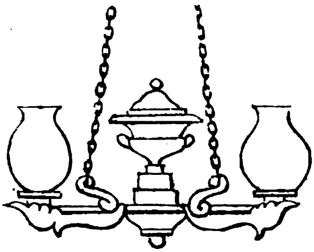

CHEMISTRY OF ARTIFICIAL ILLUMINATION.

Historical Notice.—The advantages of artificial light are so numerous and important, that they must have claimed attention from the very earliest period of history: in fact, long and long before man had commenced his work of civilization, the light of the cheerful fire must have been a source of comfort and security; for, perhaps, nothing assists so powerfully in dispelling the gloom of darkness, and banishing the terrors of night, as the lustre of a cheerful fire. And then, as civilization advanced, the usefulness of artificial light must have been perceived in a thousand ways. True, it might at first have been employed merely as a luxury among the rich, but in process of time it became a necessary even with the poor; and were we now to deprive man of all means of obtaining artificial light, the consequences would be terrible,—we should cripple his energies and impoverish his intellect,—the greater portion of his time would be lost to him,—every industrial occupation would be hindered,—the very safety of the community would be endangered,—and, in fact, the wealth and commerce of every nation would be seriously affected. These considerations endow our subject with an interest of no ordinary character; and we may truly say, that few inquiries would furnish so profitable a result as a complete history of Domestic Illumination, "tracing its gradual development from the solitary watch-lantern, graven on the pyramid, through the graceful but very imperfect lamps of the Greek and Roman period, as exhibited in our museums, and the clumsy contrivances of the middle ages, up to the productions of modern times, satisfying the demands both of taste and science. In such a narrative might be shown the progress of light, in the literal signification of the word, by a careful examination of the various forms in which it has been at different times employed,—as lamp, lantern, torch, flambeau, falot or cresset, candle, and gas,—whether for the celebration of religious ceremonies, for increasing domestic comfort, adding to the security of the streets, or forming a beacon to guide the mariner at night. It would be, at the same time, a history glancing at the advancement which the improvements in illumination have given to the social condition of mankind, and at the advantages which science has derived from the study of this subject." Besides which, there would be mixed up with such an historical account many of the fanciful hypotheses and highly-poetical conceits in respect of the nature of fire, which have at various times occupied the attention of man.

Perhaps the earliest source of artificial light was the wood-fire, blazing in the recesses of the forest, or in the hut of the savage; and then, as experience led to the discovery of the fact that different kinds of wood burn with different degrees of splendour, it must have been perceived that certain vegetable substances might be employed, in preference to others, as a means of obtaining light. In this way a splinter of pine, the resinous bark of a tree, or even the oily kernel of a nut, might early have been resorted to for such a purpose; indeed, we are told that the inhabitants of Tortuga had long used the wood of yellow sandal; those of New England made choice of a resinous splinter of pine; the natives of British Guiana selected the wood of an amyris; and in Otaheite, the candle was a row of nuts fastened upon a skewer. Again, accident must soon have taught mankind that the resinous exudations of trees, the fat of animals, and the bitumen and naphthas of the mineral kingdom, were not only highly combustible, but that, while burning, they were also highly luminous. Having learnt this fact, it required but little ingenuity to suggest the use of some porous material upon which the combustible might be smeared, or into which it might be dipped, before it was burnt. In this way the torch, the candle, and the lamp were doubtless invented.

The first authentic evidence that we have of the use of candles is furnished by Pliny in the 13th Book of his Natural History. He there says, in speaking of the lost books of Numa, that when Terentius the scribe discovered the sepulchre of the king, he found in it a parcel of books tied round in every way with *candles*, after the manner of the cere-cloth. This story is quoted from Piso, Tuditanus, Varro, Antias, and others: it is also repeated by Livy, who states that the candles were two in number. Now as Numa was the successor of Romulus, and reigned about 700 years before the birth of Christ, it is evident that candles were used in the earliest days of Roman history; judging, also, from the use to which they had been put, it would appear that they were composed of string or rope covered with some combustible, perhaps pitch or wax. It is to be regretted, however, that Pliny has not given us a more particular account of the construction of those candles; indeed, he has not informed us how any of the candles of his time were manufactured; he merely alludes to the subject incidentally. Thus, in his chapter on Willows, he says that the pith of the brittle rushes, which grow in marshy places, is used for making wicks for watch-candles and funeral-lights, to burn by a dead body while it lieth above the ground; and, in a subsequent chapter on Flax, he states that the part of the reed which is outermost and nearest to the peel, or rind, is called tow, and is good for nothing but to make lamp-match or candle-wick: nothing whatever being said respecting the material which was put about those wicks. The inference, however, is that the watch-candles in Pliny's time were like our rush-lights, and that the others were similar to the pitched rope which we employ, after the fashion of a torch, for common illuminating purpose. Fosbrooke informs us, in his Encyclopedia of Antiquities, that the candles of the ancients were sometimes made of the leaves of the papyrus covered with wax or tallow: and he remarks that common kitchen-stuff was used for such purposes as far back as the days of Augustine. A proof of this is to be found in the writings of Apuleius, who speaks of two kinds of candles—namely, the *cerei*, or wax, and the *lebacei*, or tallow.

During the middle ages wax was extensively employed for purposes of illumination; and, according to Fosbrooke, the candles were not made by regular craftsmen, but by the monks, and the servants of nobility. An illustration of this is to be found in Asser's Annals, where an account is given of the manner in which King Alfred directed his candles to be formed. "He commanded his chaplain to supply wax in sufficient quantity; and he caused it to be weighed in such a manner, that when there was so much of it as would equal the weight of seventy-two pence, he caused the chaplain to make six candles thereof, each of equal length, so that each candle might have twelve divisions marked across it." These candles, when burnt in succession, lasted for twenty-four hours, and each division indicated the third of an hour.

Up to that time the use of candles was chiefly confined to the churches, the monasteries, and the houses of the nobility; but in the fifteenth century the employment of candles had become very general; and at that time the trade of making them had acquired so much importance, that the chandlers of London obtained an act of incorporation. The candles of those days were all made by dipping the wick into the melted wax or tallow; but in the eighteenth century, the Sieur de Brez of Paris invented the plan which is now practised, of casting them in metal moulds, and later still the wax candles were made by rolling the wax around the wick. All subsequent improvements in the manufacture of candles have resulted from the very elaborate investigations of Chevreul into the composition of fats; indeed, most of his results have been made the basis of the several patents of modern time, as, for example, those of Bolts, Fremy, De Milly, Gwynne, Wilson, and others.

Lamps are also contrivances of very ancient date. They are frequently mentioned n the sacred writings; and there can be no doubt that they were much better known and more generally used than candles. Clemens Alexandrinus and Eusebius ascribe their invention to the Egyptians; but it is rather a singular fact that they were not well known in Greece during the time of Homer—at least, he has not referred to them. In his story of Penelope, he says, as most classical scholars will remember, that the suitors of Penelope paid homage to her with torches and odoriferous wood laid in a brazier. Lamps, however, were common enough in Rome during the early period of her history. Pliny frequently refers to them, and even describes the oil and the wicks that were burnt in them. The cities of Herculaneum and Pompeii have furnished us with excellent examples of both the form and the material of ancient lamps. It would appear that at first they were made of baked clay (terra-cotta), and that the design was simple in the extreme—an oval or elongated vessel, having a lip at one end for the wick; but in process of time, as the habits of the Romans became more luxurious and expensive, the material was changed for gold, silver, or Corinthian brass, and the design became more complicated. These lamps were either suspended from the ceiling or arranged in rows on a stand or candelabrum, the designs of some of which are exceedingly beautiful. The light which they furnished must have been dim and unsteady, for the construction of the lamp was always the same—namely, a solid wick immersed in a vegetable oil. Pliny says that the inhabitants of Sicily burned a kind of bitumen, resembling an unctuous or oily liquor; and that they collected it from the surface of a spring in the territory of Agrigentum. In other cases the oil which they used was of vegetable origin—it was extracted from the fruits of castor or olive; and in more recent times animal fats were employed. This was the condition of things until a very modern period, when M. Argand of Geneva effected a complete change in the art of illumination. Every one is acquainted with the lamp that bears his name, the principle of which is, that the oil burns at a high temperature with a plentiful supply of atmospheric air. This is accomplished by means of a hollow cylindrical wick, and a glass chimney which surrounds the flame. Few improvements of any practical importance have been made on this principle, notwithstanding that many contrivances have been originated, and various combustible liquids resorted to.

The history of street-lighting furnishes many examples of the slow progress with which the art of domestic illumination has advanced. At first, the only lights in the public highways were those of the cautious citizen, who deemed it prudent to make his nocturnal visits under the protection of a link, a flambeau, or a lantern. We are told that the streets of Rome, even in her palmiest days, rarely exhibited more than one or two lanterns, which were suspended over the baths and places of public resort. Now and then they were illuminated for a festival, and sometimes the forum was lighted up for a midnight exhibition; but with these few exceptions, the city was a city of darkness. In the fourth century, the streets of Antioch and Edessa were furnished with public lamps. Libanius, in his panegyric of the former, says, "The light of the sun is succeeded by other lights, which are far superior to the lamps lighted by the Egyptians on the festival of Minerva of Sais. The night with us differs from the day, only in the appearance of the light: and with regard to labour and employment, everything goes on well; for some work continually, while others laugh and amuse themselves with singing." This fact is confirmed by Jerome, who tells us of a serious dispute that was maintained for some hours in the streets of Antioch, between a disciple of Lucifer and one of the orthodox: he says that the dispute was kept up until the streets were lighted, and then the disputants spat in each other's face and retired. In the history of Jesue Stylites, we are informed that Eulogius, the governor of Edessa in Syria, ordered lamps to be kept burning in the streets during the night; and that he employed for that purpose a part of the oil which was before given to the churches and monasteries.

It is worthy of notice, however, that public illuminations, either on account of religious festivals, or general rejoicings, were very common with the ancients, and are of great antiquity. Herodotus states that the Egyptians had a festival of much solemnity, during which lamps were placed before the houses, and kept burning throughout the night; the Jews, also, celebrated their *festum encœniorum* in like manner. According to Æschylus, it would appear that the Greeks had their nights of public rejoicing; and there can be no doubt that the Romans were continually in the habit of lighting up their streets with lamps and torches, whenever an event of public importance commanded their attention. In some instances, these displays were wholly unpremeditated, as when an orator distinguished himself in the senate, or a soldier in the camp. Cicero was thus honoured when he defeated the conspiracy of Cataline; and many a Roman general has been encouraged in his march by a like display of public enthusiasm.

Until very recently, the modern cities of Europe were no better provided for in this respect than the ancient. It is true that statutes were made, and orders proclaimed, to the effect that every citizen should contribute his share to a system of general illumination. This was effected by placing a candle in each of the lower windows of the house, and keeping it burning from night-fall to the hour of twelve. At first the performance of this duty was optional, but at last it became compulsory; nevertheless, it was at all times so sadly neglected, that the thief and the assassin had abundant opportunities for mischief. Paris was the first city to improve on this condition of things; for in the year 1558 huge contrivances, called *falots*, were erected in the principal thoroughfares. The *falot* was a sort of vase filled with pitch, resin, and such-like things, in a state of combustion; but it was soon found that this mode of lighting the streets was expensive, dangerous, and inconvenient, and consequently the falot was quickly displaced by the lantern, which was a rude frame covered with horn or varnished leather. For more than a hundred years this was the plan of illumination generally adopted; and, as may be supposed, the light was too feeble for any useful purpose: indeed, no one of importance ventured abroad after dark without his torch or flambeau. The latter, therefore, became so indispensable to the midnight traveller, that an ingenious Italian, named Laudati, conceived the idea of opening stalls for their hire. He started his business in Paris in the month of March, 1662, and he managed it so well that he obtained the entire monopoly of the whole city; his charge for a link was from three to five sous the quarter of an hour, according to the rank of his customer. In 1667, Nicholas de Reynio, the first lieutenant-general of police, introduced a still better system of street-lighting. He invented lamps of glass, which from their resemblance to a bucket were called *lanternes a seau*. These he fixed in the middle of the streets exactly in the same way as they are now suspended in many parts of France, by means of ropes or wires fixed at each side of the street, the lamp being suspended in the centre.

We have no means of showing when London was first lighted with lamps; though Maitland says, in his "History of the Metropolis," that an order was issued as early as the year 1414, commanding the inhabitants to hang out lanterns for the benefit of passers-by. This information is derived from Stow, who in his "Survey of London" remarks, that "in 1417 Sir Henry Barton, the Mayor, ordained lanthorns with lights to be hanged out in the winter evenings, betwixt Hallontide and Candlemasse." It does not appear, however, that these orders were much attended to, for we find that they were repeated again and again over a period of three hundred years. At the expiration of that time the Corporation of London determined on removing the service altogether out of the hands of the inhabitants; they therefore entered into contract with a person to set up the public lights, and to attend properly to them—for which they gave him permission to charge six shillings a-year to every householder whose annual rent exceeded ten pounds. In 1736 the Lord Mayor and Common Council applied to parliament for power to light the streets in a better manner. This power was further increased in 1744; and from that time the illumination of the City has been gradually improving.

Most of the preceding facts have been derived from Beckmann, who tells us that the following are the dates when public lamps were introduced into the other cities of Europe:—Amsterdam, 1669; Hamburg, 1675; Copenhagen, 1681; Berlin, 1682; Hanover, 1696; Leipsic, 1702; Vienna, 1704; Dresden, 1705; Halle, 1728; Birmingham, 1733; Brunswick, 1765; Nantes and Versailles, 1777; Zurich, 1778; and Strasburg in the year following.

In very recent times the greatest of all improvements in street-lighting has been effected by the use of gas; and those who can remember the old-fashioned lamp, with its miserable glimmer, and the dangers which constantly beset the traveller after nightfall, will have no hesitation in saying that the employment of gas for illuminating purposes has been one of the most important events of modern time. In truth, it has not only been the means of effecting a wonderful change in the whole system of artificial illumination, but it has also produced an equally important change in the domestic concerns of the people: it has encouraged industry, developed the arts, protected property, diminished crime, and operated in a thousand ways as a medium of wealth, prosperity, and social improvement. All this has been accomplished in less than half a century; for Mr. Clegg tells us in his work on gas-lighting that he himself, in 1813, was the first to put gas into the lamps of Westminster; and he has also given us a graphic account of the fear and wonder with which it was contemplated. Now, however, it is one of the most familiar objects of daily life; for there are almost as many gas-lights in this metropolis as there are human individuals. What would Beckmann say of all this, if in the year 1786 he imagined the lighting of London to be perfect; and thought that the appearance of the City after dark, when seen from a distance, was noble and magnificent? Of a verity, his admiration would be boundless. One thing, however, is still wanted to make gas the greatest boon of the nineteenth century—that is, a guarantee in respect of its purity and harmless qualities. Already the demand for these has become urgent; and it will not be long before the gas companies of England will find it to their advantage to yield to it. In fact, the City of London has, as usual, taken the initiative in this matter, and has appointed an officer to test the quality of the gas supplied within its boundaries. The results are so important to the community, that all other cities and towns will ere long follow the example; and then we shall hope to see the art of domestic illumination made more perfect than it is at present.

ON COMBUSTION AND FLAME.

General Remarks.—Artificial light is due in almost every instance to chemical action—that is, to a rapid or energetic union of two or more substances, and the formation of new compounds. At one time it was thought that matter in the act of burning was destroyed, and thus the term combustion was used to designate the phenomena: but we now know that matter is indestructible, and that substances while burning merely change their form. In proof of this, it may be mentioned that the chemist is enabled to ascertain the exact composition of an organic substance, by simply collecting and weighing the products of its combustion. This, indeed, constitutes the principle of every organic analysis.

Those substances which evolve light and heat during their chemical union, are generally distinguished by the terms combustible and supporter,—the former term being applied to the body which burns, and the latter to that which permits of the burning. We speak, for example, of wood, tallow, and coal as combustibles, and of atmospheric air, oxygen, and chlorine as supporters; but a very little reflection will show that those expressions are altogether arbitrary, and that they might in most cases be reversed without destroying their sense. This will be clear from what follows. When coal-gas is burnt in atmospheric air or oxygen, we call the gas the combustible, and the air or oxygen the supporter; but by changing this condition of things, and igniting a jet of air in a vessel of coal-gas, we should then call the air the combustible and the gas the supporter; from which it must be evident that the phenomena of combustion are due to a reciprocal play of affinities, in which one element takes as large a share as the other; and that the distinction of property, as implied by the terms combustible and supporter, is not founded on fact: nevertheless, we still continue to make use of those terms, because of the convenience they afford in description.

Theories of Combustion.—For a long time the phenomena of combustion were thought to be dependent on the evolution of a peculiar subtle principle called *phlogiston*. This hypothesis was originated by Becher in the seventeenth century, but it was not elaborated until the days of Stahl, when it was universally accepted among chemists as the Phlogistic theory. For more than a hundred years the theory held a prominent place in the science of chemistry; and although it was founded in error, or rather in a total misapprehension of facts, yet its truthfulness was not doubted until the time of Lavoisier, when by an accurate examination of the facts he exposed its fallacy. According to the Stahlian theory, there was something—namely, phlogiston—always given out during combustion, from which it might reasonably be inferred that the body became lighter; but by collecting the burnt products and weighing them, Lavoisier showed that it actually became heavier, and that something must, therefore, have been absorbed or taken in. This something he soon found was derived from the atmosphere, and was the gas just then discovered by Scheele and Priestley. Having determined these facts, and tested their truthfulness in every possible manner, he boldly advanced his new theory of combustion, the Antiphlogistic; in which he said that the phenomena of combustion were *at all times* due to the rapid chemical union of oxygen with a combustible. Had Lavoisier been content to say that the phenomena were *usually* dependent on such a combination, it is probable that the theory would have existed in a modified form until the present time; but in his attempts to make it too general in its application, he effected its ruin: for in the course of a few years the investigations of Sir Humphry Davy into the properties and elementary nature of chlorine gas, demonstrated the fact, that combustion might be effected without the aid of oxygen at all. This was proved by the action of chlorine on antimony or copper; and from that time the phlogistic theories were put aside; and chemists have ever since regarded the phenomena in question, not as the result of any particular kind of combination, but merely as the energetic display of ordinary chemical action. And here we may remark, that there is not, perhaps, in the whole range of chemical science a subject that offers so many interesting facts for contemplation, as that to which we have just alluded; for it teaches us that the progress of human knowledge is often dependent, not so much on the discovery of great and important truths, as on the manner in which they are contemplated; and if men's minds are not prepared for the reception of those truths, they will either be disregarded, or else made the means of propagating error. This was the case with the theory of Becher and Stahl, which had the effect of distorting every fact that came under its influence. In this way for years it delayed the progress of science, and checked the development of truth. History tells us that for more than a century before the discoveries of Lavoisier, the main facts of his investigations were broadly set forth in the writings of Hooke and Mayew; but from the circumstance that those facts were premature—that men's minds were not prepared to receive them, and that chemists were infatuated and led astray by the false doctrines of Becher and Stahl—the more humble but important truths of Hooke and Mayew were allowed to pass unnoticed; and they lay dormant for more than a hundred years.

Manner in which Combustion may go on.—An examination of this question will show that most substances have the power of burning in three ways; namely, by slow oxydation, when little or no light is evolved; by a more rapid combination, when the burning becomes so hot as to render itself luminous; and by a still more energetic action when it bursts into flame. We have examples of the first of those processes in the phenomena termed *Eremacausis*, or slow burning, as is witnessed in the glowing of phosphorus, and in the luminosity of decaying wood or putrifying fish. In most of these cases, the heat and light evolved at any given moment are not very considerable; and few persons would be disposed to regard the phenomena as those of combustion; but when it becomes known that the total amount of heat, and perhaps also of light, generated during this slow kind of oxydation is exactly the same as that evolved during the most rapid combustion of the same substances, there will be no difficulty in understanding that the phenomena in the two cases are referable to the same kind of chemical action, and belong to the same category.

The second mode of combustion is observed when coal-gas, or the vapour of ether, alcohol, or wood-spirit, is mixed with air, and brought under the influence of spongy platinum or fine platinum wire. This is best effected by suspending a coil of the wire in the flame of either of the combustibles, then blowing the flame out, and allowing the vapour or gas to play on the surface of the metal: in this way the platinum will keep up the combustion, and will continue to glow, although the vapour or gas will not be inflamed.

The third kind of combustion is produced whenever a sufficiently high temperature is applied to any kind of vaporous matter so as to inflame it. The temperature at which this is effected varies with different combustibles; some take fire at ordinary temperatures, as finely-divided phosphorus, and phosphuretted hydrogen; whereas, solid or massive phosphorus requires a temperature of 140° to inflame it; sulphur takes fire at about 500°; hydrogen and carbonic oxide at 1000° (which is a red-heat); and coal-gas, ether, turpentine, alcohol, oil, tallow, and wood, at about 2000° (or an incipient white-heat); but when once inflamed, they all continue to burn at a very exalted temperature.

The Nature of Flame.—The preceding remarks will be sufficient to show that flame is nothing more than gaseous matter burning at a very high temperature. We may prove this by experiment. If we take a coil of iron-wire, or a piece of watch-spring, and arm it at one end with a fragment of burning wood, then introduce it into a jar of oxygen gas, the metal will take fire and burn with the most brilliant scintillations, but it will not produce flame. Again, if we expose wood to the action of heat in a closed vessel, so as to drive off all volatile matters and obtain its fixed solid constituent, charcoal, we may burn it in an atmosphere of oxygen without producing flame. In both of these examples, the absence of flame is entirely due to the absence of gaseous matter in the combustibles; and to show that a high temperature is necessary to produce flame, we have only to burn coal-gas, alcohol, ether, or wood-spirit at the low temperature of glowing platinum, and they will not inflame.

It may be thought, perhaps, that in the case of wood, tallow, oil, phosphorus &c., the flame cannot result from gaseous matter, because those bodies are either solid or liquid in their nature; but a little consideration will teach us that in the act of burning they all become converted into gases or vapours. This may be easily demonstrated in the case of a common candle or oil-lamp, the wick of which conveys the fluid combustible to the flame, where it is decomposed and converted into vapour. Now if we hold a small glass tube, or even a piece of tobacco-pipe, in the flame of the candle, so that the end of the tube shall be exactly over, and almost in contact with, the top of the wick, it will collect the combustible vapour and convey it out of the flame, whence it may be burnt by applying a light to the opposite end of the tube (Fig. 1). This experiment also proves that flame is hollow: it consists, in fact, of three cones placed one over the other. The inner cone, which is of a dark colour, and surrounds the wick, is formed by the vapour of the decomposed tallow. The second cone is the luminous one; it envelops the preceding on all sides, and consists of the ignited particles of the gas making its way outwards to the air. The third or outermost cone is nearly invisible; it constitutes that pale blue film which everywhere surrounds the luminous part of the flame. We may make this cone more evident by bringing a piece of thread moistened with salt into the lower edge of the flame, when the cone will be instantly lighted up with a deep yellow tinge. Another mode of discovering it is to screen off the luminous cone by means of the hand; or it may be rendered visible by intersecting the flame with a piece of fine

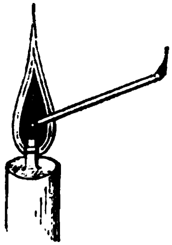

Fig. 1.

platinum wire, or wire gauze, the ignition of which discovers the exact boundary of the cone. This cone is made up of gas in an actual state of combustion; for it is here, and here only, that the process of oxydation is rapidly going on.

Cause of Light in Flame.—A little experience will inform us that different combustible substances burn with different degrees of intensity (Fig. 2). We will endeavour to show that this is wholly dependent on the number of solid particles that are ignited within the flame. If we take a jet of nitrogen gas and fire it, or make use of a flame of alcohol from a common spirit-lamp, we shall notice that neither of these bodies burn with any great amount of light; the case is very different, however, with a candle, or even with a jet of coal-gas. Now, in the former examples the hydrogen and the spirit do not contain any solid particles, and consequently do not contain any species of matter that can, by its ignition, evolve light; but in the latter examples the case is very different—for by intersecting the flame with a cold plate, we shall find that there are myriads of solid particles in the form of soot, which by their ignition produce that intensity of light for which such combustibles are valued. Again, when sulphur is burnt in oxygen gas it evolves a faint blue spectral light, that is hardly sufficient to illuminate the dial of a watch; but when phosphorus is treated in this manner, it emits a volume of light that rivals the intensity of the sun. It will be noticed that the products of the former are wanting in solid particles, whereas those of the latter are made up of myriads of white flakes of solid phosphoric acid. It is on this account that carbonic oxide and wood-spirit, as well as hydrogen, sulphur, and alcohol, burn with little or no light; while zinc, antimony, ether, turpentine, oil, tallow, and coal-gas, burn with more or less splendour. But we may communicate a great degree of brilliancy to some of the former by giving them a large proportion of solid particles; for example, when we sift a little magnesia into a jet of hydrogen, its illuminating power is at once raised to a high standard; and the same thing happens if we employ lime, oxide of zinc, or white antimony, instead of the magnesia. So also if we naphthalize the gas by passing it through a chamber containing ether, turpentine, benzole, or coal naphtha, its light is increased to that of the best description of coal-gas. In fact, coal-gas consists, in great part, of hydrogen and carburetted hydrogen, both of which are, as it were, naphthalized with other compounds that give it illuminating power. But the most striking example that we can refer to in illustration of the fact that the light of flame is dependent on the presence of solid particles, is afforded by the results obtained with the oxy-hydrogen blowpipe. When the flame of the mixed oxygen and hydrogen gases is seen as it issues from the jet without impinging on any solid substance, it strikes the observer as being an insignificant and almost invisible object; but directly it is thrown on a piece of lime or other material that will give it solid particles, it instantly becomes one of the most splendid lights with which we are acquainted: in fact, the intensity of the oxy-hydrogen light is so great, that when its rays are reflected by means of a concave mirror, they are distinctly visible at a distance of sixty-eight miles. We can easily understand,

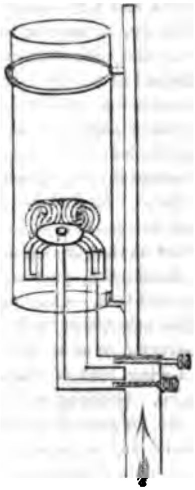

Fig. 2.

therefore, why it was so earnestly proposed by Lieutenant Drummond as a means of illuminating light-houses. So, again, with the electric light, the brilliancy of which is dependent on a number of minute particles of charcoal that are intensely heated by the galvanic current. The splendour of this light is scarcely inferior to that of the sun, for on one occasion when it was tested, it was found to be equal to that of 300,000 wax candles, and was distinctly seen at a distance of several miles.

Lastly, it may be stated, as the converse of the preceding, that we can always reduce the illuminating power of flame by diminishing the amount of solid material contained in it. To take coal-gas by way of example, we shall find that the light may be kept down, or even destroyed altogether, by blowing atmospheric air into it. This sometimes happens with the lights in the streets, and then the flame is reduced to an insignificant blue flicker. The same thing occurs if we mix atmospheric air with the gas before it is consumed, or if we employ a glass chimney that is too tall for the size of the flame. In all these instances, the solid particles of charcoal contained in the gas are burnt too speedily, and consequently there is no time for their previous ignition. This teaches us that there is one great point always to be attended to in the management of gas for illuminating purposes: we should take care that the supply of atmospheric air is so regulated that, on the one hand, the solid particles shall not be instantly consumed; and on the other, that they shall not escape as uncombined soot. Many gas-burners are constructed so as to effect this of themselves; this is the case with the fish-tail and the bat's-wing, both of which present a thin stratum of flame for the action of atmospheric oxygen. Other burners, as the Argand and its modifications, require a glass or chimney for the purpose of effecting a proper supply of air. The chimney acts by creating a draught, and so causing the air to play into the body of the flame; but if the chimney be too high, the draught will be too great, and the gas will be overburnt; whereas, if it be too low, the current of air will not be sufficiently strong, and the carbon of the gas will escape in the form of soot or smoke. As a rule, the flame should be kept at about one inch below the top of the chimney. Mr. Billow, of London, has contrived a burner, which not only demonstrates the nature of flame and the cause of its light, but also shows the effects of an under supply of atmospheric air. In ordinary burners the air is admitted to the flame on all sides, and it even passes up into its interior; but in the burner contrived by Mr. Billow the inner supply of atmospheric air is cut off, and consequently the gas is but imperfectly consumed. The result of this is that carbon is liberated, and, by the construction of the burner, it is made to girate round and round, until it collects into little solid masses, which fall by reason of their own weight; directly this happens they come into contact with a part of the flame where combustion is actively going on, and they are instantly projected into the atmosphere like so many diminutive rockets. Our readers will find a description of this burner at page 357 of the second volume of the Journal of Gas-lighting.

Quantity and Intensity of Flame.—It must have been noticed again and again by those who are in the habit of pursuing their avocations by the aid of artificial light, that there is a great difference in the practical value of different kinds of illuminating agents; for example, the eye is often most painfully excited with the strong glare of certainvarieties of light, although there is not enough of it to produce the necessary illumination of surrounding objects; on the other hand, we sometimes perceive that the light is particularly inoffensive, notwithstanding that everything about us is brightly and sufficiently illuminated. It is probable that these two conditions are entirely dependent on two states of light, which have not yet been properly appreciated. To the one we apply the term *intensity*, and to the other *quantity*. We have examples of the former in the electric-light, in the Drummond light, and in the vivid combustion which is going on in the burners of Leslie and Wingfield; of the latter in the diffused light of day, and in the illumination that is produced by a number of separated gas jets. In the one case we have comparatively few solid particles, but they are heated to a high degree of intensity; in the other we have a much larger number of ignited points, but their ignition is not carried to so high a temperature. These facts have not yet received so much attention as they deserve; and in all our endeavours to improve the quality of a burner, we should never lose sight of the fact that the human eye requires far more of quantity than it does of intensity for agreeable vision.

The Colour of Flame.—Our preceding remarks have gone to show that the light of flame is dependent on the *number* of solid particles present in it; we will now demonstrate that the colour of the light is dependent on the *nature* of those particles. The flame of alcohol or wood-spirit is naturally colourless; but we may give it various tints by saturating the spirit with different kinds of saline substances. Chloride of potassium will make it violet; boracic acid or chloride of barium, green; chloride of copper, blue; common salt, yellow; chloride of strontium, red; and chloride of lithium makes it of a carmine tint. The same substances produce a similar effect when they are sifted into the flame of hydrogen; and the pyrotechnist relies upon these properties in producing the various coloured devises which are the glory of his art. Some years ago there was an exhibition in London of philosophical fire-works; and it was described at the time as a very great novelty. It was said to be effected by the combustion of gases charged with various substances, and ignited from jets arranged in different forms, as spirals, wheels, stars, &c., the tints being chiefly red, blue, green, and purple. It is not known what were the materials used; but from the strong smell of ether and spirit in the room, there is no doubt that these liquids were among the constituents of the gases, and that they were employed as the solvents of different saline compounds: in fact, the chromatic cloud which used to attract so much attention a few years since was nothing more than the burning vapour of spirit charged with the preceding salts.

The Heat of Flame.—Under ordinary circumstances the combustion of gaseous matter takes place only at the exterior of a flame—that is, where the surface of the luminous cone is in immediate contact with the atmosphere; but we may increase these points of contact, and therefore the combustion and heat, by throwing air into the interior of the flame, or by mixing the combustible with the atmosphere before it is burnt. In this way we can increase the heat of flame to almost any extent; indeed, the principle of the common blowpipe, of which there are numerous varieties, is founded on this fact; and if we blow a jet of oxygen into a flame of coal-gas by means of a double tube, we obtain a temperature that is sufficiently high to melt platinum. A mixture of air and coal-

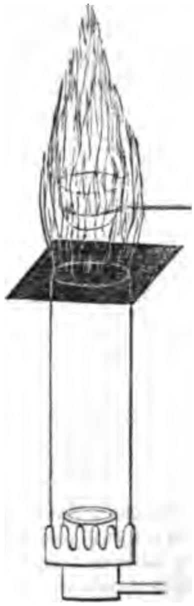

Fig. 3.

gas may also be burnt over a chimney covered with wire-gauze, and then the heat produced is sufficient to keep a small crucible at a bright red heat (Fig. 3); but the highest temperature of all is generated by the combustion of a mixture of two parts, by measure, of hydrogen gas and one of oxygen. This constitutes the mixture of the oxy-hydrogen blowpipe, which has been so useful an instrument in the hands of the chemist. Different combustible substances do not, however, produce the same amount of heat, or consume the same relative proportion of oxygen. This is an important fact, and it should always be remembered in considering the effect produced by different illuminating agents in the atmosphere of the room in which they are burnt. The following table exhibits, in approximate numbers, the relative values of different combustibles in this respect:—

Name of Combustible.	Weight of Water raised 1° by 1 of body.	Weight of Oxygen consumed by 1 of body.	Weight of Carbonic Acid produced by 1 of body.
Carbonic oxide	3650	0·57	1·57
Cyanogen gas	9380	1·23	1·70
Olefiant gas..........	21630	3·41	3·14
Marsh gas	23610	4·00	2·75
Hydrogen gas	61230	8·00	0·00
Wood-spirit..........	9930	1·50	1·37
Alcohol	12630	2·09	1·87
Rape oil	16770	2·89	2·81
Sperm oil............	16950	2·90	2·82
Olive oil	17130	2·90	2·82
Turpentine	19110	3·29	3·27
Tallow..............	14430	2·90	2·91
Wax................	16230	3·00	2·92
Spermaceti	17130	3·10	3·00
Sulphur	4580	1·00	
Phosphorus	10830	1·25	

Coal-gas is chiefly composed of hydrogen and light carburetted hydrogen, with which there is a small proportion of olefiant gas; it therefore evolves enough heat to raise about forty thousand times its weight of water one degree, and it produces about twice its weight of carbonic acid.

In order to show the advantage of well-purified coal-gas over all other materials for artificial illumination, as regards the injury done to the atmosphere of the room in which their combustion is going on, Dr. Frankland has given the following table, which exhibits the amount of carbonic acid produced by a number of illuminating agents, burnt in such quantity as to give a light for ten hours equal to that of twenty sperm candles, each consuming 120 grains per hour:—

Tallow	10·1 cubic feet.	London cannel-gas	3·0 cubic feet.
Wax	8·3 "	Hydro-carbon gas with Boghead coal-gas	2·6 "
Spermaceti	8·3 "	Hydro-carbon gas with Lesmahago coal-gas	2·3 "
Sperm oil	6·4 "		
Common London gas	5·0 "		
Manchester gas	4·0 "		

The Products of Combustion.—One of these—namely, carbonic acid—has been noticed in the preceding table; the other product of combustion is water. Occasionally there is also produced a small quantity of sulphurous acid; but, as a rule, it will be found that combustible substances are composed of only carbon, hydrogen, and oxygen. Coal-gas, however, contains a small proportion of bisulphuret of carbon, and sometimes a very perceptible quantity of sulphuretted hydrogen, both of which in burning produce sulphurous acid—the acid of the burning match; and this, by further oxydation of the air, becomes sulphuric acid, or oil of vitriol, a product which has been found to exert the most destructive influence on textile fabrics, as the covers of books, &c. Again, when coal-gas is not perfectly consumed, it generates aldehyde, volatile oil, and a few other compounds which are exceedingly offensive. This is experienced in every kind of gas-stove, where the flame is allowed to play on a large cooling or radiating surface; and hence it is advisable that gas should always be burnt in such a manner that the products of combustion may easily escape into the external atmosphere. Other illuminating agents, as tallow, oil, turpentine, &c., likewise give rise to the formation of unpleasant compounds when they are burnt at a low temperature. Every one must be acquainted with the odour of a smouldering candle or a badly-trimmed lamp; and when alcohol, or ether, or wood-spirit are burnt at the temperature of glowing platinum, they produce a number of most irritating compounds, as aldehyde, acetic acid, formic acid, &c. This teaches us that combustion should at all times be kept up with as much energy as is compatible with the required effect, and that the products of its action should be disposed of as speedily as possible.

Effect of Cooling Influences on Flame.—Every circumstance that tends to lower the temperature of flame, operates to a like extent in diminishing the intensity of its light. We see this when a large snuff collects on the wick of a tallow-candle—the carbon of which radiates the heat so fast, that the light and temperature of the flame are considerably reduced; and by bringing a mass of metal in contact with a small flame, the latter is immediately extinguished. Sir Humphry Davy was the first to investigate facts of this description; and he showed by his masterly researches that flame cannot exist below a certain temperature. This is easily proved by intersecting the flame of a candle with a piece of wire-gauze, having about thirty or forty meshes to the inch; or by endeavouring to pass the flame through a ring of stout copper-wire, or through a small hole punched in a sheet of that metal. In all these cases the flame will be extinguised above that point where the metal intersects it; and, although the inflammable vapour will continue to pass through the holes in the form of smoke, yet the cooling influence of the metal is so great, that the combustible gases will not be inflamed. The same process occurs when we place a layer of wire-gauze over the glass or chimney of an ordinary gas-burner; the wire will by its conducting power so far reduce the temperature of the flame, that it will not pass through to the apertures of the burner. Sir Humphry Davy took advantage of this important fact, and applied it in the construction of the safety-lamp, which has been of such essential service to the miner. "The Davy," as it is termed, is nothing more than a common oil-lamp, with a cylinder or cage of wire-gauze surrounding the flame (Fig. 4). This gauze permits the passage of light, but it will not allow the flame to traverse it; and hence, it may be exposed to the most inflammable mixtures without danger of explosion. The miner knows when the atmosphere of the mine is explosive, by the enlargement of the flame and the burning of the fire-damp within the cylinder of wire-gauze, and he perceives a struggle, as it were, of the flame to pass out; but such a result is not possible, unless the cooling influence of the wire is prevented by its becoming almost red-hot. In this case there is danger; and the fire-damp of the mine may be exploded. These lamps are also employed in spirit warehouses, gas manufactories, in the sewers, and in all other localities where there is risk from explosion. The same principle was employed by Mr. Hemming in the manufacture of his safety jets for the oxy-hydrogen blowpipe. We have already said that the mixed gases which are used in this apparatus are exceedingly explosive; and if some contrivance were not adopted to prevent the backing of the flame, they would assuredly take fire. In fact, in the earlier experiments with the oxy-hydrogen blowpipe, this was a result of frequent occurrence; and Mr. Clarke tells us in his work on the subject, that he often narrowly escaped being killed by the bursting of his apparatus. On one occasion, when he was experimenting in the presence of some friends, "the reservoir for the compression of the gases, although made of thick copper, was torn in pieces; and the fragments flew with the force of cannon-shot in all directions, like the bursting of a bomb." To guard against the danger of such terrible consequences it was found necessary to protect the operator by means of a thick oaken screen. Mr. Hemming saw the disadvantage of all this; and adopting the facts that Sir Humphry Davy had recently brought to light, he contrived a safety jet that enabled the operator to do away with all the paraphernalia that had hitherto protected his life. His jet consists of a tube of brass, about six inches long and three-quarters of an inch in diameter, packed full of fine copper or brass wire: the wire is cut into lengths of six inches, then packed as close as possible in the tube, and finally wedged together by means of a central bar of metal. In this way a number of fine apertures are left for the passage of the gas; and the conducting or cooling power of the wire is so great, that the flame cannot pass back to the reservoir of mixed gases.

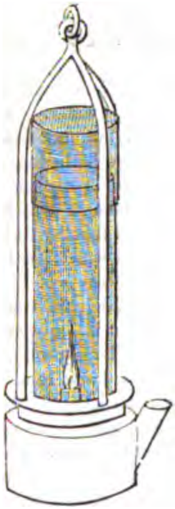

Fig. 4.

Another circumstance that operates in reducing the light and heat of flame is its rarefaction. When a flame is put under the exhausted receiver of an air-pump, it first enlarges, then the light diminishes, and finally it is extinguished. A flame of alcohol, ether, wood-spirit, wax, tallow, oil, or spermaceti, is extinguished when the rarefaction is carried to a fifth or sixth degree; hydrogen is extinguished when it is carried to a seventh or eighth degree; sulphur when it reaches the eighteenth degree; and phosphorus when it arrives at the thirtieth degree. "Slow combustion on the surface of platinum is exhibited by marsh-gas, down to a fourfold rarefaction of the air; by carbonic oxide to sixfold; by vapour of alcohol, ether, or wax, to eightfold; by olefiant gas, to ten or elevenfold; by hydrogen gas, to thirteenfold: and by vapour of sulphur, down to a twentyfold rarefaction of the air."—(Gmelin). From this it would follow that the light emitted by any illuminating agent is not so great at the top of a mountain as at its base, or in the tropics as at the poles of the earth.

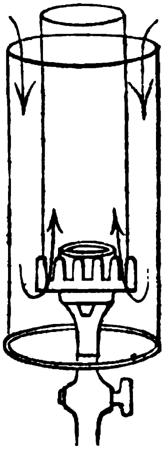

Fig. 5.

Lastly, it should be mentioned that the supply of very cold air to a flame always diminishes its light by the abstraction of heat; and hence we may improve the illuminating power of any combustible substance by supplying it with atmospheric air that has been previously warmed. The Rev. Mr. Bowditch, of Wakefield, has contrived an apparatus whereby this may be effected in the case of common gas. He places a disc of metal or a cup of glass, having a hole in its centre, on to the screw which receives the burner. This disc or cup is made the means of supporting an outer glass, and thus of directing the air down over the surface of the hot chimney before it enters the flame from below (Fig. 5). It is stated that the light is increased about 25 per cent. by this arrangement.

ON THE LAWS OF LIGHT AND RADIANT HEAT.

General Remarks.—We know nothing of the ultimate nature of light and heat, any more than we do of the nature of gravitation: indeed, there is no necessity for such knowledge; for, as in the case of the latter, all the phenomena may be thoroughly investigated, and their application satisfactorily made, without the slightest reference whatever to the abstract question of their ultimate cause. The only philosophical definition that can be given of these agents is, that they are the cause of certain phenomena, of which the sensations of vision and warmth are the most important. The laws which govern their manifestation are, in the two cases, almost identical; for the rays of both are propagated in straight lines, and traverse space with great velocity; they are also reflected, refracted, absorbed, dispersed, and polarized in exactly the same manner. We may here remark, that when the rays of light and heat impinge on any surface, they are disposed of in one or more of several ways: they may bound off or be reflected. They may pass through the body and undergo refraction or double refraction; they may be polarized, dispersed, or broken up into other rays; and they may also be absorbed or smothered.

Intensity of Light and Heat.—We know that the power of light and heat diminishes as we recede from any object that produces it, and the decrease is in proportion to the square of the distance; for example, if we have a certain amount of light; at a foot from its source, the intensity will be one-fourth at two feet, because the square of two is four; one-ninth at three feet ($3 \times 3 = 9$), one-sixteenth at four feet ($4 \times 4 = 16$), one twenty-fifth at five feet ($5 \times 5 = 25$), and so on. Upon this law, as it is termed, is founded all the methods now employed for estimating the relative value of different illuminating agents. The practice is called *Photometry*, and there are various modes of conducting it. Count Rumford adopted the plan of adjusting the lights at such a distance from an upright rod, that the shadows produced by each on a white screen should be equal; he then measured the distance of each light from the rod, and on squaring the number of inches he obtained two sets of figures which represented the relative values of the lights: by dividing the larger sum by the smaller, we obtain a product that expresses the fact in simpler terms. The late Mr. Ritchie contrived an apparatus that consisted of two pieces of glass, placed at a right angle to each other, and so disposed, that the light from two opposite sources should be reflected upwards upon a piece of tissue-paper that covered two holes in a darkened chamber. When he had adjusted the instrument so as to obtain two reflections of equal intensity, he then measured the distances and proceeded as before. Leslie and Wheatstone have also invented photometers, which are useful enough for certain purposes; but they have all given place to the very simple contrivance of Professor Bunsen. It will be noticed that if a piece of white filtering-paper is painted over with melted wax or spermaceti, it acquires a greasy appearance and becomes translucent: if this be done so as to leave a spot or disc, about the size of a shilling, untouched in the centre of the paper, we shall find that the apparatus will have the following properties:—When examined by reflected light—that is, with the light on the same side of the paper as the observer is—the disc will look white and the surrounding greasy part dark; but by altering this condition of things, and looking at the paper by transmitted light—that is, with the light on the opposite side of the instrument—the disc will appear dark, and the surrounding greasy portion light and translucent. Lastly, if two lights of equal intensity are placed one on each side of the paper, the disc will disappear entirely; for then the light of one side neutralises that of the other, and there is no disposition to produce either effect. Upon this is founded the principle of Bunsen's photometer. The instrument consists of a graduated rod about five feet in length, having a support at each end. The prepared paper is held by a frame which slides upon the rod between the lights. This frame is usually enclosed in a darkened chamber, so as to exclude all light but that emanating from the object to be tested. The frame containing the paper is slid to one side or the other until the disc entirely disappears, and thus we read off the relative values of two lights. In making experiments on coal-gas, it is usual to burn it at the rate of five cubic feet an hour, from an Argand burner having fifteen holes and a seven-inch chimney. The candle, which is used as a standard for comparison, is generally of sperm, and the rate of consumption is fixed at 120 grains per hour. When it happens that the consumption is greater than this, it may be reduced to the normal standard by a very simple calculation; thus—suppose that on experiment it was found that the light of the gas was equal to eleven candles of 140 grains' consumption; then as 120 grains is to 140, so is 11 candles to the standard value—namely, 12·8 candles.

In this way the following results have been obtained; and, in order that an estimate might be made of the relative values of different illuminating agents in respect of their consumption and heating power, other results have been appended:—

	Consumption of each candle or burner per hour.	Number required to produce the same light.	Total consumption per hour.	Illuminating power in standard candles.	Heating power in lbs. of water raised 1°.
Cannel coal-gas . . .	3·5 cub.ft.	2 burners	7 cub. ft.	28	4550
Common " . . .	5 " "	" "	10 " "	"	6500
Sperm oil in Argand . .	450 grs.	5 lamps	2250 grs.	"	5448
Sperm candles, 6 to lb. .	134 "	25 candles	3350 "	"	8223
Wax " " .	167 "	23 "	3841 "	"	8904
Cocoa-nut " .	143 "	26 "	3718 "	"	8664
British sperm " .	140 "	29 "	4060 "	"	8743
Composition " .	144 "	30 "	4320 "	"	8906
Oil in common lamp .	133 "	36 lamps	4788 "	"	11595
Tallow moulds, 6 to lb. .	143 "	40 candles	5720 "	"	11793

The amount of heat, in these cases, has been determined by burning the lamp, or candle, under a vessel containing a given quantity of water, or in a space surrounded by a certain amount of that liquid, at a known temperature: from which it will be evident that, for the same amount of light, cannel-gas produces the least heat; then follows sperm oil in an Argand or carcel-lamp; then common coal-gas; then wax, sperm, and other candles; and, finally, oil in a common lamp, and tallow candles—both of which produce an enormous amount of heat in proportion to the light evolved.

Reflection.—When a beam of light or a ray of heat falls on a polished surface, a large portion of it bounds off or is reflected; and it will be found that the angle at which it bounds off is precisely the same as that at which it falls upon the surface. This fact is expressed in the law of reflection,—namely, that the angles of incidence and of reflection are equal. This law holds good under all circumstances, whether the angle be acute or obtuse, and whether the surface be plane or curved. The instruments that are used to reflect light or heat are called mirrors, specula, or reflectors; and they are commonly made either of polished metal or of glass silvered on one side. Their surfaces are either plane, concave, or convex; each of which produces its own particular effect. Plane mirrors do not alter the direction of the rays, but simply throw them off in the same manner as they receive them; in consequence of which they always produce an exact image of the object, both in respect of form and size; and the image invariably appears as if it were situated as far behind the mirror, as the object in front of it. The convex mirror has the effect of scattering or diverging the rays, and the peculiarity of its action is to produce an image of small size, and, as it were, at a great distance. The reverse is the case with the concave mirror; and hence this form is employed for magnifying objects, or for throwing the rays of light, or heat, to a great distance: for when it happens that parallel rays fall upon a concave mirror, they are brought to a point, or focus; while divergent rays, as from a lamp or candle, are made parallel. Mirrors of this description are, therefore, used in light-houses, because their effect is, to collect the rays from the lamp, and to throw them off in nearly a parallel direction, to a great distance.

Instruments for reflecting light have been employed from a very remote period. We learn from the 38th chapter of Exodus that the Egyptians used mirrors of brass; and Pliny informs us that the mirrors of his time were made of polished silver. Many persons are of opinion that Archimedes, two hundred and twelve years before Christ, employed mirrors for the purpose of focussing the sun's rays; and that by means of a combination of such instruments he set fire to the fleet of Marcellus, as it lay before the walls of Syracuse. To test the probability of this opinion, Father Kircher and his pupil Schotus visited that city, and made many experiments; the results of which were, that Archimedes could easily have performed such an exploit by the aid of a number of mirrors. Indeed, Buffon was so convinced of its practicability, that he went to the expense of having three hundred and sixty plane mirrors erected in a frame in such a manner that they all threw the sun's rays upon one spot. By means of this instrument he was enabled to melt pumice-stone at a distance of forty feet, and to kindle wood at a distance of two hundred and ten feet. Beckmann informs us that in the middle ages mirrors of steel were commonly used, and that in the thirteenth century they began to use mirrors of glass.

Transparency and Transcalency.—These terms are applied to designate the property which certain substances possess of allowing the rays of light and heat to pass through them; and while on the one hand it may be stated that nearly everything in nature is in certain states of tenuity more or less transparent and transcalent, so on the other hand it may be said that nothing is perfectly so. Even in the case of the diamond, of pure water, and of atmospheric air, all of which appear to be so exceedingly pellucid, a large portion of light and heat are always destroyed in thus passing through them, and we lose a considerable amount of light by placing glass globes over the flames of oil or gas.

Melloni has devoted much attention to the subject of the transmission of heat through different media; and the results of his investigations are to the effect that there are no direct relations between the transparency of a body and its power of transmitting heat. In fact, many substances, as blackened glass and black mica, will not allow light to traverse them at all, although they freely admit the passage of heat; and, on the other hand, many transparent bodies, as alum and sulphate of copper, are not at all transcalent. If 100 rays of heat fall on colourless glass, only 40 are transmitted, while yellow glass stops 78 per cent.; blue glass, 79; and deep violet only 66. Rock-salt is the most transcalent body known; it allows 92 per cent. of the heat of a lamp to pass through it; rock crystal, 38; white agate, 23; borax, 18; Rochelle salt, 11; amber, 11; alum, 9; white sugar-candy, 8; ice, 6; and sulphate of copper, 0. Among liquids he found that turpentine transmitted 31 per cent.; ether, 21; oil of vitriol, 17; and water, 11. These facts admit of many practical applications, especially in those cases where we wish to preserve the light but not the heat. In the oxy-hydrogen microscope, for example, a film of sulphate of copper is sometimes used to keep off the heat from the cells containing the delicate microscopic creatures which are the subjects of experiments.

Refraction.—The rays of heat and light are endowed with the power of passing through many substances; and when it happens that those substances are of greater or less density than the medium just traversed, the rays are invariably broken out of their original course. This is called refraction; and we shall find that when the rays pass from a denser into a rarer medium, they are refracted or broken out of their course away from the perpendicular; and conversely, when they pass from a rarer into a denser, they are broken towards the perpendicular. This is illustrated by placing a coin in a basin, when the light reflected from the coin at the bottom of the basin reaches the eye in the direction of a crooked line, thereby giving rise to a notion that the coin is situated higher up against the side of the basin. A stick also looks crooked when partly immersed in water, by reason of the same cause; and it may be mentioned that a fisherman in spearing salmon, or a fish in striking at a fly, must always make compensation for this refractive power, or the object will be missed. The degree to which this takes place varies with the medium and the figure of its surface; but there is always the same relation for the same medium, between the angle of incidence and the angle of refraction. If these angles are measured from the surface instead of the perpendicular, and the former angle is called one, then the relative refractive powers or angles of different media will be as follows:—diamond, 2·54; sapphire and ruby, 1·78; topaz, 1·64; flint glass from 1·6 to 2·; crown glass, 1·53; rock-salt and rock-crystal, 1·56; alum, 1·46; the lens of the human eye, 1·38; fats and oils, 1·49; turpentine, 1·47; alcohol, 1·37; ether, 1·36; salt-water, 1·34; common water, 1·33; carbonic acid gas, 1·53; atmospheric air, 1·; oxygen gas, 0·92; and hydrogen gas, 0·47.

By taking advantage of this refractive power of transparent solids, we are enabled to construct instruments that have the power of diverting the rays of heat and light from their original course, and of bringing them to a focus. These instruments are called prisms and lenses: the former are triangular, square, or five-sided; the latter are spherical, doubly-convex, plano-convex, doubly-concave, plano-concave, and concavo-convex or meniscoid. Each of these has its own particular action; that of the doubly-convex and plano-convex is to focus the rays of light and heat when they are parallel, or to make them parallel when they are divergent. The bull's-eye of the policeman's lantern, and the lamps employed for signals at railway-stations, are constructed on this principle. They act by collecting the very divergent rays from the lamp, and throwing them in a parallel direction to a considerable distance.

Burning lenses have been used for a very considerable period of time; they are described by Aristophanes in his "Comedy of the Clouds," which was written about 430 years before Christ; but the most important facts connected with the focussing of the sun's rays have been investigated within the last century or so. Tschernhausen, in 1680, made several glass lenses of three or four feet in diameter; one of which weighed 160 lbs., and had a focus of twelve feet. Homberg employed it in the course of his inquiries, and found that when the sun's rays were focussed by it, he could burn up all the metals then known, and even melt slate and pottery. In the year 1773, a large lens was constructed in France under the direction of M. de Trudaine, and placed in the garden of the Infanta at the Louvre. It was composed of two large concave glasses, each four feet in diameter, with a radius of eight feet: they were joined together at the edges, and thus formed a chamber capable of holding thirty-five gallons of liquid. When filled with water they focussed the sun's rays at a distance of twelve feet; with alcohol at ten feet ten inches; and with turpentine at seven feet. The heating power of the apparatus was so great that it fused iron immediately. But the most splendid instrument of this kind was made a few years ago by Mr. Parker of Fleet Street: it was composed of flint glass, and cost about £700 in its manufacture. The heating power of the lens was enormous. Those who experimented with it, said it was as high as 1096° of Wedgewood's pyrometer, the zero of which is a red-heat. Some idea of its calorific power may be formed when it is stated, that with the rays of the noon-day sun it melted twenty grains of gold in four seconds, ten of platinum in three seconds, a topaz in forty-five, an emerald in twenty-five, a piece of flint in thirty, and a piece of pumice-stone in twenty-four seconds. Besides which it inflamed green wood and boiled water directly they were put into its focus.

Dispersion of Light and Heat.—When a ray of light or heat traverses any refractive medium, it is not only broken out of its course, but it is also decomposed, dispersed, or broken up into simpler parts. This is particularly evident in the case of light, and Newton was the first to direct attention to the fact. His mode of conducting the experiment, so as to demonstrate this, is still followed. If a beam of white-light enter a dark chamber and fall upon a triangular prism of glass, the beam will suffer both refraction and dispersion—that is, it will not only be broken out of its course, but will be split up into colours; and when these are received upon a screen of white paper, it will be found that the nature and order of the colours, beginning from the bottom or least refracted, are as follows,—red, orange, yellow, green, blue, indigo, violet. The image thus produced is called the Newtonian spectrum; and the colours were once thought to be the components of white-light; but a little attention to the subject will show that four out of the seven tints are compound, and that there are but three primitive colours—namely, blue, red, and yellow. The beautiful effect produced by the lustres of chandeliers is dependent on the dispersive power of the glass composing them; and in nature the rainbow, and the rich tints of the setting-sun, are examples of dispersion produced by the agency of water and the atmosphere. The three tints to which we have alluded are called the complement of white-light; and whenever it happens that these are not present in the true proportion to form the light of day, there is a longing on the part of the eye for the full complement, and the organ of vision becomes fatigued and harassed if it is not gratified. To take an example: we soon feel tired if we exercise the eye by the light of gas; this arises from the circumstance that gas-light is too yellow, or rather reddish-yellow, in its tinge, and the eye longs for the blue rays to make up the complement. These can easily be supplied by means of blue glasses, or blue reflectors; and with such assistance, especially in the field of the microscope, where the eye is seriously tried, vision can be sustained for a longer period, and with greater comfort. In addition to the coloured beams which are thus produced by the prism, there are other rays that enter into the composition of white-light: these are the rays of heat and of chemical action. The former are chiefly located at a short distance below the red, although many are also scattered about in other parts of the spectrum. This has led opticians to believe that heat undergoes dispersion, and that there are different varieties of these rays, as in the case of light; but, from the circumstance of our not possessing an instrument or organ like the eye for judging of these differences, the opinion is founded rather on analogy than on actual experiment. The chemical or actinic rays are situated a little above the violet; and they are the agents that are concerned in the production of Daguerreotype and other light pictures.

Lenses, like prisms, also effect the dispersion of light; and hence in all the common kind of microscopes, telescopes, and opera-glasses, the object appears to be fringed with colours. This, however, is now corrected by a plan originally contrived by Mr. Dolland: it consists in the juxta-position of two lenses of different composition, one being made of flint-glass and the other of crown. By this contrivance the dispersion of one medium is neutralised by that of the other; and hence the object appears in its proper tints, with a sharp and well-defined outline.

Besides these properties of light and heat, there are others to which we can only refer; namely, those of *double refraction*, *polarization*, and of *being affected by a powerful magnet*. Double refraction is effected by passing the ray through a medium of unequal density, as in the case of calc-spar, when the object looks double; and polarization is accomplished by passing it through a tourmaline, or by reflecting it from different substances at certain angles. Finally, the magnetization of light and radiant heat are manifested when the rays are sent through certain media which are under the influence of powerful electro-magnets.

CANDLES.

Materials employed in Candle-Making.—It has been already remarked that candles are among the most ancient of illuminating agents, and it cannot be doubted that originally they were manufactured in a very rude way, by simply smearing a porous combustible solid with animal fat; but at the present time a number of fatty substances are employed in their manufacture, and great pains taken to have them as pure as possible. We have, for example, tallow and its derivatives stearine and stearic acid, margarine and margaric acid; palm oil and its constituents, palmitin and palmitic acid; cocoa-nut oil, cocinin and cocinic acid; spermaceti, wax, paraffin, &c. All these require to be purified before they can be converted into candles; and hence the necessity for describing them in detail.

The *wicks of candles* are of three kinds, namely, the pith of a rush (*Juncus effusus*), which grows abundantly in marshy places; and of cotton, which is either rolled into skeins or plaited into strands. The first is used for the common rush-light, the second for ordinary dips and for wax-lights, and the third for spermaceti, stearic acid, stearine, and other candles which do not require snuffing. In many cases it is necessary to prepare the wicks with a salt of ammonia, as the phosphate, borate, or sulphate, in order to keep them from clogging, and to give them a sufficient degree of rigidity to enable them to stand firmly up when they are burning. This was an improvement introduced in 1836, by M. De Milly, of Paris. Dr. Ure says that the best wicks are still imported from Turkey, and they are composed of skeins of unbleached cotton. The wick of wax mortars and night-lights are made of flax, as cotton is not able to resist the long-continued action of the high temperature of the flame.

Varieties of Candles and their Manufacture.—Two sorts of candles are commonly met with in commerce, namely, *dips* and *moulds*. The former are made by repeatedly dipping the wicks into melted fat, allowing a sufficient time between each of the dippings for the tallow or fat to cool. Usually the wicks are cut into proper lengths, according to the sort of candle to be made, and then suspended from a rod or frame, called a port; by this means the workman is enabled to dip a number of candles at the same time. In large establishments the ports or frames are attached to a revolving beam, so that, without much exertion, the workman can successively dip one port after another, and thus make from seven thousand to eight thousand candles in a day. The tallow is kept in the dipping-vessel at a temperature just over the setting point.

Mould candles are made in a tubular mould, which is either of pewter or glass. The mould consists of two parts, namely, the cylinder and the cap. The former is of the full length of the candle, and is highly polished in the interior, so as to allow the candle to slip easily out of it. The latter is a small cup, having a hole in the centre for the passage of the wick; it is fixed on to the bottom of the cylinder, and serves to give the taper-form to the top of the candle. Sometimes there is a third piece, called the foot, which is a sort of funnel, that is screwed on to the opposite end of the cylinder, and serves for the guidance of the melted fat into the mould. Eight or ten of these cylinders are usually fitted into one frame, which has the upper part formed into a trough for the reception of the melted tallow. The wicks are drawn into the cylinders by a hooked wire, and kept in their places by a wedge, which fixes them in the cap of the mould; the other end being held by a rod which passes across the frame. When all is ready, the liquid fat is run into the trough, and thence into the moulds, until each cylinder is full. After it has thoroughly cooled, the surplus fat is scraped out of the trough, and, the wedges being removed from the hole in the cap, each candle is drawn out of its mould by means of a hooked wire, which catches hold of the loose end of the wick. The candles are then cut of one uniform length, and trimmed up for the market.

The cheaper sort of mould-candles are those manufactured by Price and Company, and are made by machinery; eighteen candles being moulded at one time. The wicks are made in lengths of sixty yards; eighteen of these wicks are wound off upon eighteen separate rollers, and a roller is placed over each mould. The wicks having been passed through the cylinder, are seized at the lower end by a set of eighteen forceps, which draws them tight and fixes them in their places. The moulds, which during the operation have remained in a horizonal position, are now turned in a vertical direction, the small end downwards, and are passed upon a railway to the person who fills them. In their course they have traversed a hot closet, and have thus acquired a proper temperature for receiving the tallow. When full, they are pushed on to other railways, and allowed to cool. This being accomplished, they are brought back in succession, by means of turn-tables, to their former places. The frame is then placed in a horizontal position; and eighteen plungers or pistons press forward the loose caps of the moulds, and thus push out the candles, and deliver the wicks for another operation.

Wax and Paraffine Candles are usually moulded by hand, in consequence of their sticking so tight to the sides of the mould, that they cannot be drawn out of it. The operation for wax candles is conducted as follows:—The wicks are first warmed in a stove, and then suspended to a hoop over the vessel of melted wax. The latter is then poured from a ladle over each wick in succession; and to prevent the wax from accumulating more on one side of the wick than the other, the wick is sharply rotated between the finger and thumb. When the candles are thus coated to about one-third their proper size, they are allowed to cool for a short time, and the operation is then repeated until they are half-made. This being accomplished, they are removed from the hoop, and rolled between two marble slabs until they are of one uniform thickness. The upper end of each candle is now formed by cutting it down to a metal tag, which covers one end of the wick. The candles are then again suspended to the hoops, but in a reversed position; and the operations of basting and rolling are repeated as often as necessary. Finally, the lower ends of the candles are cut square, so as to make them of the desired length.

The large wax candles used in churches are formed by rolling the wick in a thin layer of wax, and then, after adding layer after layer, it is finished off in the usual way.

Long wax tapers are made by winding the wick on a drum, and then leading it by means of a guide-roller into a trough of melted wax, from which it passes through a series of holes progressively smaller and smaller on to a second drum, where it is wound up—the operation being somewhat like that of wire-drawing. A little turpentine is added to the wax to render it pliable, so that it may not crack as it bends over the drum.

We proceed now to speak of the different kinds of fats, and of the candles made from them.

Tallow is obtained from animals; it is the fat which is located under the skin, about the intestines, in the bones and muscles, and around the kidneys. It is extracted by cutting the tissue into small pieces, then submitting it to heat, and finally to pressure. The tallow or fat of bones and the dressings of skins is obtained by boiling them in a large caldron, and skimming off the fat as it rises to the surface. A large quantity of tallow is obtained from meat during the ordinary operations of cooking; and this is known in commerce by the name of kitchen-stuff. Tallow, when first obtained, has a very disagreeable smell; indeed, it contains a great number of impurities, as blood, animal tissue, water, &c.; and in this condition it is not suited for the manufacture of candles. To render it pure, it is submitted to various operations, which are called *rendering*. One of these is as follows:—The tallow is melted in a large copper set upon an open fire, and the water contained in the impure fat is boiled away; during this stage of the operation the animal tissues and bloody matters coagulate and rise to the surface. These are strained off and pressed, the residue is sold under the name of greaves or cracklings, and is used for feeding dogs. Another mode of rendering is to submit the melted tallow to the action of steam, which is blown into it from a pipe pierced with a number of holes. But the most effective process of all is that recommended by M. D'Arcet: the tallow is melted by steam-heat, and then treated with very dilute sulphuric acid; this destroys the colouring matter, and separates the animal tissue in the form of black flakes, which speedily settle to the bottom of the vessel. After drawing off the tallow, and washing it well with warm water, it is allowed to stand until it rises to the surface and is cold. In this state it is nearly free from colour and smell. Some years ago Mr. Watt obtained a patent for purifying tallow by a mixture of acids, as sulphuric, oxalic, nitric, and chromic; the two latter of which give out oxygen gas, and thus bleach the fat.

Tallow consists of several fats; one of which (oleine) is liquid at ordinary temperatures, and the others (margarine and stearine) are solid. Occasionally also, when it has been obtained from particular animals, it contains a few other fats, as hircine, butyrine, &c. The relative proportions of these fats give to tallow its different consistence; for example, beef-marrow or bone-fat, which is rather hard, contains 76 of stearine to 24 of oleine; mutton fat, 62 to 38; beef fat, 54 to 46; butter, 40 to 60; hog's-lard, 38 to 62; goose fat, 32 to 68; and turkey fat, 26 to 14. Again, this melting point of different tallows varies with the proportions of these constituents; for while common tallow melts at from 94° to 104°. Fah., marrow fat requires a temperature of 115° to liquefy it, and hog's-lard is fluid at 81°.

Most of the tallow imported into this country comes from Russia; a large quantity also arrives from South America, Australia, and the United States of America. Some idea may be formed of the relative proportions supplied to us from those countries by the following table, which shows the amount of tallow imported into England in 1850:—

Russia	803,697	cwts.
South America	184,321	„
Australia	179,567	„
United States	32,523	„
Other parts	18,993	„
Total	1,219,101	„

In addition to which 1,067 lbs. of tallow candles were imported from various places.

Three sorts of candles are made out of ordinary tallow; namely, rush-lights, dips, and moulds. The former are not much employed in towns, except for watch-lights; but they are still the favourite candle with the poor in country villages; and it is very probable that they are chosen because of their not guttering so much as the common dip when they are exposed to currents of air: besides which, they burn longer, and are therefore more economical. In many cases these candles are made by the peasants themselves. Mr. Gilbert White has given an account, in his "Natural History of Selbourne," of the manner in which they are produced by the cottagers of Hampshire. They take a quantity of rushes, which have been previously peeled, and dip them into the melted tallow, so that six pounds of tallow shall serve for 1600 rushes. In this way they produce candles which require 228 to make a pound. The rushes are peeled on three sides for the best lights, and on two only for watch-lights, and which, says Mr. Gilbert White, only shed a dismal one—darkness visible. Of the other kind, a good one, which measured 2 feet 4½ inches in length, burned 57 minutes; and he was assured by an experienced old housekeeper that 1½ lb. of rushes, after having been coated with tallow, completely supplied her family for a year. The cost of lighting with rushes he estimated at one farthing for 5½ hours; whilst a halfpenny candle, in the blowing, open rooms of the poorer classes, only lasted two hours. The rush-lights that are sold in London vary from ten to eighteen in the pound. A specimen of ten to the pound, which measured

11½ inches in length, burnt at the rate of 1½ inches in the hour, or 74 grains, and it took five of them to give the light of one sperm of 120 grains per hour.

Ordinary dips burn with great irregularity—even the same candle will vary from 120 to 180 grains per hour; and when consumed at the standard rate, they give a light which is just one-third that of sperm. Dips are made of all sizes from six to sixteen in the pound; and they are sold at from *5d.* to *7d.* per pound.

Mould candles of tallow are generally made of the better description of fat—they are therefore whiter than dips, and melt at a little higher temperature. A mould candle of six to the pound burns at the rate of about 143 grains per hour, and its illuminating power is rather more than half that of a sperm of 120 grains; so that, weight for weight, its powers is about half that of sperm.

The disadvantages attending the use of tallow candles are, that they melt at a very low temperature, and are therefore not suited for warm climates or hot rooms; they gutter when they are exposed to draughts; they constantly require snuffing; they give out an unpleasant smell, both before burning and after; they soil the hands and grease everything with which they come into contact; and in warm weather they are very apt to break. Some of these disadvantages have been overcome by the chandlers of Dublin, many of whom have acquired a high reputation for the superior quality of their mould candles; and it has been found that by waxing the wicks before they are used for making the candles, the disposition to gutter, which is so objectionable, is in a great degree prevented. Candles of this description generally fetch from a halfpenny to three farthings a pound more than the commoner sort.

Palm oil is the produce of the *Elais Guiniensis*, or *Avoira elais*, a palm that grows very abundantly in the tropical parts of Africa. Most of the palm oil that we receive into this country comes from the western coasts of that continent—chiefly from Guinea. It is obtained by crushing the fruit, then submitting it to the heat of boiling water, and finally to pressure. The oil has a buttery consistence, is of an orange-yellow colour, a sweetish taste, and an agreeable odour. When new it melts at a temperature of 81° Fah.; but if old, it requires a heat of from 90° to 96° to liquefy it. It consists of about 69 of oleine, and 31 of a solid fat named palmitine. The crude oil is readily bleached by exposing it to light and air, or to chlorine gas, and it may also be purified in the same way as common tallow. Until it is deprived of its great excess of oleine, it is not fit for the manufacture of candles. The quantity of palm oil annually imported into this country amounts to about 500,000 cwts. In the year 1849 it amounted to 493,331, of which 475,364 came from the western coast of Africa; 13,349 from the United States; 3,719 from the Canary Islands; 525 from the Brazils; 353 from Madeira; and the rest from Naples and Sicily. The late war, and the consequent deficiency of Russian tallow, led to large increase both in the demand and in the price of palm oil.

Galam or Ghea butter is another fat oil that closely resembles palm oil: indeed, it is very often mistaken for it. It comes from the western parts of Africa, and is the produce of a palm, the *Micadenia* or *Bassia Parkii*—a tree that is very similar in its appearance to the *Bassia latifolia*, and the other species of *Bassia* that are indigenous to the province of Hindostan. According to Park, the tree is very abundant in Bambara; and the oil is obtained from the fruit in the same way as palm oil. Ghea is of a greyish-white colour; it melts at a temperature of 97° Fah., and consists of about 68 of oleine, and 32 of a solid fat like palmitine. It is used for the same purposes, and in the same way, as palm oil.

Cocoa-nut oil or fat is extracted from the kernel of the common cocoa-nut, which is the fruit of a palm named *Cocos nucifera*. The oil is semi-fluid, or rather buttery, in its consistence. It melts at a temperature of 68°, and contains two or more fatty principles, one of which, namely, the oleine, amounts to about 71 per cent., and the other, cocine or cocinine, to 29. The oil is not fit for the manufacture of candles until it has been submitted to cold and pressure. We import this oil from several parts of India, from the islands of the Pacific, from Australia, and from Borneo. In the year 1850, the quantity shipped to this country amounted to 98,040 cwts.; of which 85,096 came from India; 6,315 from Australia; and the remainder from Borneo and other places.

Several kinds of vegetable fats or butters, well suited for the manufacture of candles, have at various times been sent to this country; but the demand for them has not been sufficiently great to encourage a trade. Among these may be mentioned the solid fats obtained from three species of *Bassia*, indigenous to India. These are, *Ilpa oil*, or *Eloopei unnay*, which is expressed from the seeds of the Illupie tree, or *Bassia longifolia*—a tree that is very abundant in the Madras Presidency, and in the southern parts of Hindostan. This oil is white, and it requires a temperature of from 70° to 80° to melt it. Similar fats are obtained from the seeds of *Bassia latifolia*, of the Bengal Presidency, and *Bassia butyracea*, of the province of Dotee—the former is named *Epie* or *Mahowa seed oil*, and the latter *Phoolwa* or *vegetable butter*. A solid oil, of a pale greenish colour, is obtained from the tallow-tree of Java—probably a species of *Bassia*, which is common not only to Java, but also to the western countries of the Archipelago. In fact, it appears from the observations of Mr. Lowe, that several kinds of solid oil are obtained in the islands of the Archipelago from different species of *Dipterocarpus*. These oils are hard, yellowish-green, and brittle, and they melt at about 90° of Fah. An oil named *Piney tallow* is expressed from the fruit of the panoe tree (*Vateria indica*), which grows abundantly in Malabar and Canara. The oil is white, solid, and fusible at 97°; it makes excellent candles, which do not give out any unpleasant smell in burning. *Cocum oil*, or *Kokum butter*, is obtained from the seeds of a kind of mangosteen (*Garcinia purpurea*), which is common in several parts of the peninsula. It is of a pale greenish-yellow colour, and it melts at 95°. *Kali-ziri*, or *Khatzum butter*, another variety of fat oil, is in all probability the produce of the seeds of *Vernonia anthelmintica*, or of *Salvadora persica*, both of which are common in Guzerat and Concan Ghats; it is a bright green oil, of the same fusibility as the last. The seeds of *Carapa Guianensis*, of Guiana and Acagie, yield a semi-solid oil named *Crab* or *Carapa oil;* and, lastly, a solid fat called *Neem oil*, or *Vaypum unnay*, is obtained from the ripe fruit of the margosa tree (*Melia azadirachta*). All these fats might, if necessary, be largely supplied to this country, and thus be the means of keeping in check the high price of tallow, or even of taking its place altogether.

Stearine, Margarine, Palmitine, Cocine or Cocinine, &c., are the names applied to the solid fats contained in tallow, suet, lard, palm oil, ghea butter, cocoa-nut oil, &c. It has been already stated that none of the raw fats, except tallow, can be applied at once to the manufacture of candles; but they must be subjected to certain processes in order to remove the oleine or liquid constituent, and so obtain the fats in a more solid state.

As far back as the year 1799, Mr. William Bolt took out a patent in this country for the manufacture of candles from compressed tallow. This perhaps was the first attempt ever made to improve the quality of candles by fabricating them from the solid constituents of fats and oils. About twenty years after this, the researches of Chevreul gave an impetus to the discovery of Bolt, by showing that all the fats consisted of at least two proximate elements—namely, an oily or liquid portion, which he named oleine, and one or more solid constituents which he called stearine, margarine, &c. Taking advantage of this fact, the candle-makers soon adopted a process whereby they were enabled to separate the one fat from the other, and thus to procure a material which would not melt at so low a temperature as ordinary tallow. To effect this the tallow, palm oil, or cocoa-nut oil is melted, and then allowed to cool as slowly as possible, taking care that it is constantly agitated during the whole time that it is setting. When the mass has acquired a pasty consistence it is transferred to horse-hair or linen bags, and submitted to great pressure. In this manner the oleine is squeezed out, and the solid fats are left in nearly a pure state. By repeating tke process of liquefaction and pressure, the stearine, margarine, palmitine, and cocinine are obtained still purer. In this condition they are perfectly white, hard, and nearly free from greasiness, and they melt at a much higher temperature than the original fats; for example, common tallow melts at from 99° to 104° of Fah., whereas stearine, which is obtained from it, melts at 144° and margarine at 117°. Palm oil is fluid at from 90° to 96°, but palmitine requires a heat of 124° to melt it; and lastly, cocoa-nut oil is liquid at 68°, while its solid constituent cocine or cocinine is fusible at 110°. These fats are employed in the manufacture of *composition* and *Palmer's candles*. The former burn at the rate of from 140 to 155 grains per hour, and they furnish a light which is scarcely inferior to sperm; the latter have an average consumption of about 160 grains per hour for each wick, and the light emitted is in the same ratio as the former.

Stearic, Margaric, Palmitic, Cocinic, and other solid Fatty Acids, are obtained from the preceding; indeed, the solid fats which have just been described contain in each case a still more solid compound, which bears the name of the fat from which it is derived. These acids were discovered by Chevreul in the year 1823; and two years afterwards he thought them of so much importance, that he allied himself with Gay Lussac, and took out patents in this country and in France for their manufacture. But, notwithstanding that they furnished candles of the very best description, and have since been made the basis of most profitable speculation, they did not realize any advantage whatever to the original patentees; in fact, the processes of Chevreul and Gay Lussac were so complicated and expensive, that they could not be followed out with profit or advantage: in addition to which, it was found that the candles manufactured from the fatty acids would not burn with an ordinary wick; and hence the necessity for still further improvement in this direction. Cambaceres, however, overcame this difficulty by inventing the present description of plaited wick; and this was afterwards improved by De Milly, who suggested the use of boracic acid and the salts of ammonia for impregnating the fibres of the cotton. Another obstacle to the use of the fatty acids was the pertinacity with which they crystallized; thus rendering the candles brittle, unsightly, and irregular of combustion. An attempt was made to remedy this by introducing fine powders into the melted acids, so as to break their grain; but then it was necessary to use powders of a volatile nature which would not clog the wick, and in an unfortunate moment they made choice of white arsenic. The introduction of this deadly poison into candles soon created alarm, for they produced very injurious effects on those who inhaled the vapours of combustion; and, in fact, it brought the discoveries of Chevreul into so great disrepute, that it almost annihilated the infant art of stearic candle-making. "It is true," say the jurors in their report on the candles of the Great Exhibition, "this deleterious substance was added in very minute quantities, yet it was entirely incompatible with health, and was soon prohibited on the continent by authority, and in England by equally powerful public opinion. Here commenced all the manufacturer's troubles anew. In all directions he sought a substitute, and yet found none: at last, after innumerable experiments, and when almost driven to despair, he hit on two simple expedients that answered the purpose in the most admirable manner. Those were the addition of a very minute quantity of wax to the melted fatty acids, or the allowing the acids to cool almost to the point of congelation before they were poured into the moulds. By this means a sort of liquid pulp is obtained, which sets in the moulds without crystallizing. This is the plan adopted in the present time; the melted acids being constantly stirred during their congelation, and the moulds warmed to a temperature of about 110° Fah. before the semifluid mass is poured into them.

The preceding account is, however, but a mere outline of the progress that has been made during the last twenty years in this important branch of industry. It may be now said that it engages a larger capital and occupies more attention than all the other modes of candle-making put together. In this country, for example, there are two companies—namely, Price's and the British Sperm, which produce annually about 2000 tons of stearic candles. In Austria the Apollo and Milly Companies furnish to commerce at least 1600 tons per annum. In France there are about twenty-five companies, which produce no less than 7800 tons of stearic candles in the year; and in Belgium, Spain, Prussia, Denmark, Holland, Norway and Russia, there are, on the average, about 500 tons manufactured in each country during the twelve months.

Two, if not three, distinct processes are employed at the present time for the preparation of the fatty acids. These are the saponification process of De Milly, and the oil of vitriol process of Fremy; besides which there is a modified process of De Milly's which is practised by Jaillon, Monier, and Co., at La Villette, near Paris.

The saponification process is founded on the discoveries made by Chevreul in the year 1823, namely, that when fatty matters are boiled with potash, soda, or lime, they are converted into soap by the union of the fatty acids with the alkali; and from this soap the acids may be obtained in a more solid condition by the action of a stronger acid, as sulphuric or muriatic. Chevreul saw the importance of his discovery, and took out a patent for the manufacture of the acids from soaps made with potash or soda. These, however, were found to be far too expensive; and in the year 1831, De Milly directed attention to the use of lime. From that date until now the process has been gradually advancing towards its present state of perfection.

The following is an outline of the process as it is conducted at the works of the Apollo Company, at Vienna; of De Milly, in Paris, Brussels, and Vienna; and of the British Sperm Candle Company, in this metropolis. The process is divided into three stages, namely, the saponification of the fat; the decomposition of the soap by a strong acid; and the removal of the liquid oil and other impurities by means of pressure.

(*a.*) *The saponification of the fat* is effected by melting the tallow, or the palm oil, in a large vat, by means of steam which issues from a pipe perforated with holes, and then stirring in a quantity of lime in the state of thin cream; 10 or 15 parts of dry lime being used for every 100 of fat. The mixture is kept in a state of ebullition for five or six hours, or until it is completely saponified. It is then allowed to stand, in order that the impurities may settle to the bottom, and the melted soap rise to the surface and cool. The soap thus formed is very hard, and is generally called rock. It is ground to a coarse powder, and is then ready for the next operation—

(*b*.) *The decomposition of the soap by a strong acid.* The ground rock-soap is placed in wooden vats lined with lead, and, after being drenched with water, it is raised to a boiling temperature—the heat being applied in the same way as before. At this moment the soap is treated with dilute sulphuric acid, using about 25 of the strongest acid to every 100 of tallow or palm oil. In this way the soap is decomposed; its lime unites to the acid of the vitriol to form sulphate of lime, or plaster of Paris, which either dissolves in the water or else settles to the bottom of the vat, while the fatty acids are set free and float to the surface. These are called "yellow matter;" and, after having been well washed with warm water, they are poured off into vessels called "jacks," and from thence into shallow tin pans, where they cool.

(*c*.) The cakes thus obtained consist of the solid and liquid acids of the fat; to separate which they are placed in horse-hair bags, and subjected to hydraulic pressure, gradually increased up to about six hundred tons. This is extended over a period of six or eight hours, during which the liquid oleic acid runs out and carries with it the brown colouring matter of the fat, leaving the solid fatty acids in a nearly pure condition. It is generally thought necessary to remelt the acids, and to treat them with a little dilute sulphuric acid, so as to remove iron and other impurities that may have been acquired in the art of pressing. After this they are again cast in shallow pans, then placed in bags, and submitted to a more moderate pressure of about forty tons. During the last operation the cakes are slightly warmed in an atmosphere of steam, so as to facilitate the removal of the last portion of oil. In this way a solid mass is obtained which has all the appearance of ivory; and the product amounts to about thirty per cent. of the fat originally used.

The second or vitriolic acid process for obtaining the fatty acids was originated in 1836, by M. Fremy, who discovered that these acids have the power of combining with concentrated sulphuric acid, to produce compounds which are named sulpho-stearic, sulpho-oleic, sulpho-margaric, sulpho-palmitic, and sulpho-cocinic acids. These are readily decomposed when they are brought into contact with boiling water, the vitriolic acid being dissolved by the latter, while the fatty acids are set free and float to the surface. This fact was made the basis of two patents, which appeared in the year 1840. One of these was taken out by Mr. George Gwynne, who proposed that the fats should be separated from the acid by distillation; and the other was obtained by Mr. George Clark, who advised that the acids should be set free by simply washing the product. But neither of these patents produced successful results; and it was not until the year 1844 that the process was so perfected by the labours of Jones, Wilson, and Gwynne, as to be applicable to the purposes intended. In that year the names of Wilson and Gwynne are found associated in a patent which still continues to be in force. The process adopted by those patentees is now extensively practised at the works of Price's Candle Company, at Vauxhall and Battersea; and at those of MM. Masse and Tribonillet, at Paris; of Motard, at Berlin; of Bert, at Gijon, in Spain; and at one of the works of the Milly Company, at Vienna.

The fats usually employed for this purpose are, palm oil, refuse grease from glue-making and bone-boiling, and ordinary tallow. The process is as follows :—

1st. *The Decomposition of the fat with Sulphuric Acid.*—This is accomplished by first melting the oil or fat in a leaden vessel by the aid of steam, then allowing it to stand for a short time in order that the mechanical impurities may subside. The liquid fat is now pumped into another vessel and heated to a temperature of 350° Fah. While in this state it is subjected to the action of strong sulphuric acid—using about 6 lbs. of acid to

112 lbs. of palm oil. The acid quickly decomposes the oil and gives it a black colour. It is now drawn off from the acid, and transferred to a washing tank, where it is boiled up with water by means of a jet of steam. After two or three washings it is ready for the next operation.

2nd. *The Distillation of the fatty acids by means of very hot steam.*—The dark liquid fat of the washing-tank is conveyed into a copper still, where it is heated to a temperature of 560°, and submitted to the action of steam that has been heated to a very high degree by passing through a system of pipes set in a furnace. The hot steam raises the fatty acids into vapour, and carries them over into a series of vertical pipes, which act as condensers. These are kept at a temperature of 212°; and consequently they retain the fatty acids, but do not arrest the steam. Towards the end of the process it is necessary to elevate the temperature of the furnace in which the still is set, and also to raise the heat of the steam in order that the whole of the fatty matter may be distilled over. The residue in the still after this operation looks like pitch, and may be employed for the same purposes.

3rd. *The cold and hot pressing of the fatty acids.*—These are effected in the same way as that described in the saponification process.

The other process to which we have referred—namely, that portion at the works of Jaillon, Monier and Co., at La Villette, near Paris, is a modification of De Milly's lime process. It consists in passing a rapid current of sulphurous acid into the lime vat while the rock mass is forming; and thus of increasing the amount of solid fat by the conversion of the liquid oleic acid into solid elaidic. In this way the very commonest tallow may be used, for the sulphurous acid acts as a bleaching and deodorizing agent. The subsequent stages of the process are the same as De Milly's.

Lastly, it may be said that a large quantity of the fatty acids which enter into the composition of ordinary soap are obtained at the grease-works of Mr. Banwens, at Wakefield, from the waste lyes and suds of the woollen, silk, and cotton manufactories. It is calculated that about 11,000 tons of fat and oil are annually expended in this country in the cleansing and preparing of the fabrics in question. Hitherto all this had been allowed to run to waste; but the energies of Mr. Banwens having been directed to the subject, it is hoped that the larger portion of the fatty acids contained in the soap and oil will be retrieved. These acids are worth about £15 a ton; and if only half of them are annually recoverable, as much as £93,500 will be annually secured. The acids are obtained by treating the boiling suds with a little oil of vitriol or spirits of salt—the liquefied fats rise to the surface, and when cold may be skimmed off or otherwise collected. The fats are then cast into blocks and pressed in the usual manner.

In whatever way the solid fatty acids are obtained, they always present the following characters:—They have the appearance of ivory, or of fine spermaceti: they are inodorous, and do not communicate a greasy stain to paper or soil the fingers: they melt at a much higher temperature than the original fats: indeed, the melting-point of pure stearic acid is 167°; that of bassic acid, which comes from the palm fats of India, is 159°; that of palmitic and margaric acids 140°; and that of cocinic acid from cocoa-nut oil is 110°. It rarely happens, however, that these acids are obtained perfectly free from a small proportion of liquid oleic acid; and hence the melting-points of the acids, as found in commerce, are a little below the preceding. Stearic candles generally melt at from 130° to 132° Fah.

The candles made from these acids are much in vogue. They are known by the names of *British sperm*, *Paris sperm*, *Belmont sperm*, *Fairfield sperm*, *Victoria Regia* or

Victoria sperm, and *Bougies de l'etoile* or *Bougies du phare;* and when tinted with a little gamboge they are called *British wax*, *Fairfield wax*, or *Paris wax*. Their prices vary from 1*s.* to 1*s.* 3*d.* per pound. The candles of six to the pound burn at the rate of from 140 to 144 grains per hour, and they give a light as nearly as possible the same as sperm. If there be any difference, the light of sperm is a little greater, and that of stearic acid a little whiter. When calculated into an average consumption of 120 grains per hour, it will be found that, for equal weights consumed, 15 sperm candles will give the light of 16·5 stearic. The advantages which are attendant on the use of these candles are, the great regularity of their burning, the dryness of the cup below the flame, the absence of all disposition to gutter, their not softening in warm climates or hot rooms, and their not soiling the fingers or clothes. It is very probable that stearic candles will, ere long, supersede every other description of *bougie*.

The candles which are manufactured by Price and Co., from the fatty acids obtained by the distillation of *Chinese vegetable tallow*—the product of *Stillingia sebifera*—are even more infusible than the last; for they require a temperature of 136° to liquefy them. A patent has been taken out by Messrs. Wilson, Gwynne, and Wilson, for the manufacture of candles from this material.

Composite or Composition Candles.—These are of very uncertain composition. Some are made from the crude fatty acids that distil over during the second stage of the oil of vitriol process; others are made of stearic acid, stearine, and the solid part of cocoa-nut oil. The former are the composite candles of Price and Co. They are very greasy to the feel; they gutter whenever they are exposed to a draught; they melt at a temperature of from 104° to 118°; and they burn at the rate of from 141 to 155 grains per hour. The average illuminating power, when reduced to the standard consumption of 120 grains per hour, is one-sixth less than that of sperm. In fact, it takes 20 of the worst kind of composite candles, or 16 of the best, to give the light of 15 of sperm. The other kind of composition candles is not so fusible as the last, and they are superior in many respects. Composite and composition candles vary in price from 8*d.* to 11*d.* per pound.

Spermaceti.—This remarkable fat is chiefly obtained from the great spermaceti whale, or great-headed cachalot (*Physeter macrocephalus*), which inhabits the Pacific Ocean, the Indian Ocean, and the China Sea. It is also obtained from other species of cachalot, as the *Physeter catadon*, *trumpo*, *cylindricus*, *microps*, &c.; and from the two kinds of dolphin, viz. the *Delphinus tursio* and *edentulus*. The spermaceti is found in all parts of the bodies of these animals, mixed with the common fat or blubber; but the great receptacle for it in the *Physeter macrocephalus* is a large excavation or case, situated in the upper jaw, directly in front of the skull and above the nostrils. This receptacle is opened by the whalers directly the animal is captured; and the liquid contents, consisting of oil, spermaceti, and cellular matter, are dipped out. The dense mass of cellular tissue, called junk, which lies immediately beneath the case, is also removed; and when boiled, it furnishes an inferior kind of oil and spermaceti. The contents of the case are carefully boiled, and then strained off into casks. In this state it goes by the name of "head-matter"; and is composed of spermaceti and sperm oil. After standing for some time at a temperature of from 40° to 50° Fah., the spermaceti solidifies as a dirty-brown crystalline mass. This is separated from the oil by straining through bags, and pressing. The crude spermaceti is melted by the aid of steam, and then allowed to cool very slowly; after which it is ground to powder, placed in bags, and subjected to enormous pressure—a pressure of six hundred tons. In this way the residue of the oil is squeezed out of it, and the spermaceti which remains is nearly white. To purify it still more, it is melted in a large iron vessel, and boiled for some time with a solution of caustic soda. This has the effect of converting all the oil with which it is contaminated into a soap, which dissolves in the water, while the spermaceti floats to the surface. It is now run into tin pans and allowed to cool. The mass so obtained is crushed to a powder a second time, and then pressed as before; the operation being conducted in an atmosphere heated by steam. Finally, the spermaceti is boiled with a strong solution of potash; and when it is perfectly limpid and colourless like water, it is cast into square blocks.

In this condition it is named *cetine:* it is a white crystalline solid, with a pearly lustre and greasy feel. It melts at a temperature of 120°; and it consists of a fatty acid (*cetylic*), which fuses at 131°, and a species of alcohol, named *ethal*, which melts at 118°. Impure kinds of spermaceti liquefy at from 112° to 160°.

Spermaceti candles contain about three per cent. of wax, which is added to break the grain or to prevent crystallization. A sperm candle of six to the pound burns with great regularity if it is properly made; but those in commerce at the present time are but poor examples of what such candles should be, for they range in combustion between 120 and 146 grains per hour. A spermaceti candle of six to the pound, burning at the rate of 120 grains per hour, is generally taken as the standard of comparison for all other illuminating agents, for the light emitted is clear, white, and very brilliant. The candles which are sold under the name of *transparent wax* are only sperm candles coloured with a little gamboge. The price of sperm candles is from 2*s.* to 2*s.* 2*d.* per lb.; the best varieties have a slightly bluish tint, and they ought not be become greasy in the warmest room. The quantity of spermaceti made use of in this country is not very considerable. In the year 1850, 5,792 tons of head-matter were imported, besides 1,120 lbs. of spermaceti, and 728 lbs. of sperm candles.

Wax is obtained from several sources: it is secreted between the abdominal scales of the honey-bee, and formed by that insect into honey-comb. The insect wax of China is produced by the male of the *Coccus ceriferus*, which deposits it on the trees on which it feeds, especially the *Rhus succedaneum.* A soft, tenacious, mahogany-coloured wax is obtained in great quantity at the Brazils, and is the product of a black bee which hives under ground. Vegetable wax is procured from the berries of several myrtles (the *Myrica cerifera*, *augustifolia*, *latifolia*, *&c.*), which grow abundantly at the Cape of Good Hope, and in South America: besides which, there are many trees in Japan and St. Domingo which yield substances resembling wax; these are the *Croton sebiferum*, *Celastrus ceriferus*, and *Ceroxylon audicola.* A wax-like substance, named *cerosine* by Dumas, is also obtained from the surface of many species of sugar-cane; and Mulder informs us that the skins of apples and the berries of the mountain-ash yield abundance of wax: in fact, wax is a very common product of the vegetable kingdom—it forms the bloom of fruits and of young leaves, and it is a large constituent of the green and yellow colouring matter of plants (*Chlorophylle* and *Xanthophylle*).

The wax of English commerce is procured from honey-comb: the comb being first allowed to drain in order to remove the honey, after which it is boiled up with water, and permitted to stand until cold, when the wax solidifies upon the surface in a brownish-yellow cake. This is purified and bleached by the following processes:—The wax is cut by machinery into very small fragments, and put into a vat with water and a little concentrated sulphuric acid,—the proportion of acid being a pint to a ton. Steam is then blown into the vat by means of a coiled pipe pierced with holes; and the mixture is kept in constant agitation. After a time it is allowed to stand quiet, when the impurities subside to the bottom, and the wax floats to the surface as a clear and almost colourless liquid. It is now run into a trough named a cradle, which has a number of holes about the size of a quill in the bottom of it. This trough is placed over a drum or wooden cylinder, which revolves in a tank of water: the melted wax, running in small streams upon the revolving wet drum, is floated off upon the surface of the water in the form of exceedingly thin strips or flakes, called ribbons. These are collected at the opposite end of the tank; and after being drained in baskets, they are spread out upon tables, and exposed to the air and light to bleach. This occupies a period of from five to ten weeks, during which the flakes are frequently wetted and turned. They are also melted and ribboned once or twice during the process, in order that fresh surfaces may be exposed, and the whole acted on in one uniform manner. When the wax is sufficiently white it is melted in vats and cast into thin cakes.

Different kinds of wax bleach with different degrees of facility: thus the wax of England, Hamburg, Odessa, Portugal, Mogadore, Zanzibar, the East and West Indies, and North America, bleach very rapidly; while those of Cuba, Dantzic, Kœnigsberg, Gabon, and Gambia, bleach with difficulty; and the soft mahogany-coloured wax of the Brazils cannot be bleached at all.

Pure wax is solid up to the temperature of 148°, but unbleached wax melts at from 144° to 146°. It contains about twenty-two per cent. of a peculiar fatty acid (*cerotic*) which was formerly named *cerine;* and the remainder consists of a compound substance named *myricine*, which Mr. Brodie says is composed of the solid acid of palm oil (*palmitic*) and a species of alcohol which he has named *oxide of melissyl*. Chinese wax is entirely free from myricine, and is made up of cerotic acid and an alcohol named *oxide of cerotyl*. Cerine and myricine are distinguished from each other by the following properties:—Cerine is soluble in boiling alcohol, from which it is deposited as the spirit cools; but myricine is wholly insoluble in that menstruum. Cerine melts at from 162° to 172°, while myricine fuses at as low a temperature as 147°.

Wax candles are rarely composed of pure wax, but consist of wax and stearine or stearic acid in various proportions. The candles of commerce are very irregular in combustion; in fact, they burn from 135 to 175 grains of wax per hour; and they give a light which varies from one up to three, according to the condition of the wick. At the best of times the light of wax is, weight for weight consumed, about one-sixth less than that of spermaceti. The cost of wax candles is from 2*s*. 2*d*. to 2*s*. 4*d*. per lb.

We do not employ much wax in this country for candle-making, as preference is now given to sperm and stearic candles; but on the continent it is still made use of to a great extent in the fabrication of candles for religious purposes, and also for holiday and fête occasions. In the Greek Church wax and oil are the only illuminating agents allowed; and in the Romish Church large wax tapers are also employed during divine service. These, as well as the candles for weddings, fêtes, and saint-days, are generally ornamented either with spirals of gold, or with different devices in colours,—the colours being artificial ultramarine for blue; a mixture of verdigris and emerald green, or verdigris alone, for green; chromate of lead or gamboge for yellow; vermillion for red; and madder lake or alkanet root for pink. The best description of candle manufactured from wax is the *mortar-light*, which is used either for night-watching or for heating dishes on the table. On the continent these lights are termed *veilleuses*.

The quantity of crude wax imported into England during the year 1850 amounted to 10,751 cwts.; besides which there were 1,076 lbs. of wax candles imported. Most of our wax is received from Gambia. In Russia, where there is a large consumption of wax in the religious services of the Greek Church, as much as £60,000 are annually expended in wax candles.

Paraffine.—About twelve years ago the sagacity of Liebig led him to remark that "it would certainly be esteemed one of the greatest discoveries of the age, if any one could succeed in condensing coal-gas into a white, dry, solid, odourless substance, portable and capable of being placed upon a candlestick or burned in a lamp."—(Familiar Letters on Chemistry, page 158.) In the course of the last few years this grand result has been effected; indeed, we may say that the germ of the discovery was brought to light more than twenty years ago by the researches of Reichenbach and Christison. The former of these chemists showed that the thick heavy oil procured by the distillation of tar from beech-wood, contained a solid crystalline body which he named *paraffine;* and the latter, in examining Rangoon petroleum, discovered a substance which he called *petroline.* Both of these compounds are identical in their chemical composition with the illuminating principles of coal-gas, and they are now known to be one and the same thing. The term paraffine is still employed to designate the substance, in consequence of its weak affinities (from *parum* little, and *affinis* affinity). Since that time it has been procured by Mr. Rees Reece and Sir Robert Kane from peat; by M. Ettling and Mr. Brodie from wax; by Mr. Young from Boghead coal; and by others from the bituminous schists of England, France, and Germany. In all cases it is obtained by destructive distillation; and the following are the processes which are commonly employed.

The plan proposed by Reichenbach was to distil wood-tar to dryness, and to separate the heavy oil which is thus obtained from the water and light oil that also come over during the process. This is distilled a second time, and only the last portions are retained. These are treated with concentrated sulphuric acid, then with water, and finally with boiling alcohol, from which the paraffine separates in the form of crystalline plates as the spirit cools.

Mr. Reece's process is to distil peat in a sort of blast furnace, to the top of which a condensing worm is attached. The air supplied at the bottom of the furnace keeps up an imperfect combustion of the peat, and the products are conveyed into the worm, where they are condensed. The greasy tar which subsides is collected and heated to a temperature of 100°; it is then submitted to the action of strong sulphuric acid, and afterwards boiled in water. The paraffine collects on the surface, and solidifies as the water cools. It is now ready for distillation; and when so treated it furnishes three products—namely, a very light oil (*eupion*), which first comes over, then a heavy oil, and finally paraffine. The light oil is separated from the mixture of the other two by decantation. When the latter is allowed to cool, the paraffine separates in the form of very minute grains; and on submitting the pasty mass to pressure in linen bags, the oil is squeezed out, and the paraffine obtained in an impure condition. The next step of the process is to deprive the paraffine of its smell and colour by the aid of chlorine and chromic acid; it is then washed, redistilled, cooled, and pressed a second time. Finally it is submitted to the action of steam until it is perfectly white and free from odour. It is said that a thousand parts of Irish peat will furnish from ten to twelve of paraffine.

Mr. Young's process is somewhat similar to the last, but he employs Boghead coal in the place of peat. The coal is distilled from a closed retort at a low red heat, and the products are treated in the same way as the last. One hundred parts of Bathgate coal will yield about forty of oil which is fit for lubricating machinery, and ten of paraffine.

Two years ago a patent was obtained by Mr. Brown for the preparation of this substance from bituminous coal and bituminous schist. The process which he adopts is not essentially different from Mr. Young's. The schist is heated in an iron retort, and then exposed to a current of very hot steam. The steam carries over all the volatile matters—namely, the oils, the tar, and the paraffine. These are condensed in a proper receiver; and the semi-solid tar and paraffine are afterwards distilled and then purified by means of sulphuric acid and oxide of manganese, or bichromate of potash. After the residue has been washed with boiling water and weak soda, it is distilled a second time; then cooled, strained, and pressed. The last purification is effected by heating it to a temperature of 400° with strong sulphuric acid. By this means all foreign matters are destroyed; and when washed with boiling water and a solution of soda, it is allowed to set, and is then ready for the market.

Pure paraffine is obtained in the form of brilliant silvery scales when it crystallizes out of boiling alcohol; but the paraffine of commerce is an amorphous substance, having the appearance of a very transparent wax. It is entirely without odour, and it does not communicate a greasy stain to paper. It is slightly flexible, and when warm may be moulded into any shape. It melts at a temperature of 110°, and distils at a red heat, unchanged. Ether, naphtha, the volatile and fixed oils, dissolve it very readily; and it mixes freely with wax, stearine, and the fatty acids. The light emitted from it varies with the size of the wick: when a small plaited wick is used the light is clear, brilliant, and free from smoke; but when the large cotton strands of wax candles are employed, the flame is large, yellow, and very smoky. The experiments which have hitherto been made with this substance, in order to determine its illuminating power, are not sufficiently complete to enable us to judge of its value; but the candles which we have burnt are consumed at the rate of from 166 to 185 grains per hour; and the light emitted has, weight for weight of candle consumed, been exactly one-twelfth less than that of sperm. It is presumed that the price of paraffine candles will be about 2*s.* per pound. At present they are not met with in commerce; but specimens were exhibited in 1852, by Mr. Young, of this country, and by MM. Masse and Tribouillet of France.

LAMP-OILS AND SPIRITS.

Classification.—Oils are divided by chemists into two kinds, namely, *fixed* and *volatile.* The former communicate a permanently greasy stain to paper or cloth, and the latter do not. Olive oil may be mentioned as an example of one, and turpentine of the other. Again, the fixed oils are subdivided into those which become thick or gelatinous on exposure to the air (*drying oils*), as linseed and poppy; and those which do not (*fat oils*), as olive and sperm. The cause of this change will be referred to directly; but it may be remarked, in a general way, that drying oils are not adapted for combustion in lamps, on account of this disposition to become thick and so to clog the wick.

The composition of oils is very much the same as that of the solid fats or butters; they consist, for example, of two or more ingredients, namely, *liquid oleine*, which is always present in very large proportion, as from 70 to 90 per cent., and *solid margarine* or *stearine.* In addition to this, many of the animal oils, as sperm, whale, seal, fish, &c., contain a volatile fat, which gives them their peculiar odour. In the case of whale and seal oils, this is called *phocenine.* The relative proportion of the solid and liquid constituents of different oils is subject to great variation, and hence the difference in the property of solidifying or becoming thick during cold weather. It must be stated, however, that all oils deposit a solid tallow-like material when they are subjected to cold; and when this deposit is very considerable in amount, as is the case with the oils of cocoa-nut, lard, olive, &c., such oils are not well adapted for burning in lamps unless they are used in rather warm places.

The sources of oils are very extensive; in fact, they are found in both kingdoms of nature. Animals yield to us lard and tallow-oil, sperm, whale, porpoise, seal, walrus, herring, cod, ling, and other such oils; while vegetables furnish us with the oils of almond, olive, rape, colza, cocoa-nut, linseed, hemp, mustard, poppy, cotton, teal, sessama or gingilie, castor, &c. In the former case the oil is obtained either from the cellular tissue which lies immediately beneath the skin, or else from the liver; and in the latter it is procured from the fruit, or the cotyledons of the seeds.

The modes of extraction vary with different circumstances; so much so, that it is scarcely possible to give a general description of the numerous processes adopted. In the case of lard, tallow, and cocoa-nut oils, the solid fats are slightly warmed, then enclosed in linen or horsehair bags and submitted to enormous pressure—a pressure of from four hundred to six hundred tons. The common fish-oils, as those of the herring, pilchard, and sprat, are obtained by piling the fish into heaps or walls, and then weighting them with stones. The oils from the livers of fish, as the cod, skate, ling, &c., are procured by boiling the livers and skimming off the oil, or else by crushing and pressing, or by allowing them to putrefy, so that the tissue may break up and let out the oil. The fat or blubber of different species of whale, porpoise, seal, dolphin, walrus, &c., is subjected to heat in iron vessels, and then submitted to pressure; and, lastly, vegetable oils are procured by first crushing the seeds, then enclosing the bruised mass in bags, and exposing to enormous pressure: this is obtained either by hydraulic power, or by screws, or by wedges driven by heavy stamps. "Linseed, rape-seed, poppy-seed, and other oliferous seeds," as we are informed by Dr. Ure, "were formerly treated for the extraction of their oil by pounding them in wooden mortars with pestles shod with iron, set in motion by cams driven by a shaft, turned with horse or water-power; then the triturated seed was put into woollen bags, which were wrapped up in hair-cloths and squeezed between upright wedges in press-boxes, by the impulsion of vertical rams, driven also by a cam mechanism. In the best mills, upon the old construction, the cakes obtained by this first wedge-pressure were thrown upon the bed of an edge-mill, ground anew, and subjected to a second pressure, aided by heat now as in the first case. These mortars and press-boxes constitute what are called Dutch mills. They are still in very general use, both in this country and on the continent; and are by many persons supposed to be preferable to the hydraulic pressure."

Sometimes the crushed seeds are exposed to the action of heat and a little moisture during the operation of pressing. This facilitates the flow of the oil, and consequently makes the seeds yield a larger produce; but the oil is never so good under these circumstances, as it contains much colouring matter, together with mucilage or vegetable mucus, and sugar; all of which diminish the combustibility of the oil, and render it very liable to become rancid. In the former case the oil is said to be *cold drawn*, and in the latter *hot*. The amount of oil obtained in this manner varies with different seeds, and even with the same seeds in different countries and seasons. Walnuts and hazelnuts usually furnish about half their weight of oil; poppy seeds, nearly half; olives, about one-third; rape-seed, a third; and that variety named colza, about two-fifths;

hemp-seed, a fourth; almonds, a fourth; linseed, from one-fourth to one-fifth; and the seeds of grape, or wine-stones, about one-tenth.

Olives are sometimes allowed to ferment, so as to become soft and pulpy before they are crushed and pressed. In this way they yield a larger proportion of oil, but the oil is not good, and is only fit for lamps or machinery.

We shall take occasion to notice more particularly the details of all these processes when we come to the subject of the individual oils.

Refining or Purifying.—In the state in which oils are first obtained from plants and animals, they always contain impurities, as albumen, vegetable mucus, colouring matter, sugar, rancid acids, &c. These must be removed before the oil is fit for combustion in lamps; and several processes are adopted for this purpose. Sometimes the oil is merely exposed to the action of steam or boiling water; and, after having been well agitated therewith, it is allowed to stand until the oil floats to the surface in a clear or pellucid condition: it is then drawn off by means of a syphon or tap, and so separated from the water which holds the impurities. At other times it is boiled with weak alkaline solutions, or with lime water, and allowed to repose. Dossic's process for purifying fish-oils is as follows:—To each gallon of oil an ounce of powdered chalk, and half an ounce of recently slaked lime, are added: after standing a short time, about half a pint of water is carefully stirred in, and the mixture is agitated at intervals of two or three hours for a period of several days. At the expiration of that time a solution of one ounce of pearlash in four ounces of water is stirred in, and the stirring is kept up at intervals for several hours: after this, two ounces of salt dissolved in a pint of water are poured in, and the mixture is agitated occasionally for the next two days. It is then allowed to stand until it becomes clear; and if the oil is not sufficiently pure and free from odour, the process is to be repeated, taking care that the quantities of the ingredients are reduced one-half.

The plan that is usually adopted for the purification of oils is founded on the fact, that concentrated sulphuric acid, in small quantity, has the power of decomposing the impurities of oil without touching the oil itself: but in carrying out the process, care must be taken that oil of vitriol is not added in too great quantity, or allowed to act for too long a period. The process is generally conducted in the following way:—About one *per cent.* of commercial sulphuric acid is cautiously added, little by little, to the impure oil; in those cases where the oil clots with strong acid, as happens with linseed oil, the vitriol acid must be diluted with about half its bulk of water before it is added. The mixture is then stirred for several hours, in order that the acid may be brought into contact with all the impurities in the oil; the stirring is generally effected by means of a sort of churn or spindle with cross pieces, which is kept slowly revolving in the vat containing the mixture. In the course of a few minutes after the vitriol is added, the oil becomes discoloured; and after the agitation has been kept up for some time, the impurities clot together in the form of flakes. When this happens the oil is allowed to stand quiet; and in the course of a few hours the flakes subside and leave the oil in a clear and almost colourless condition. The oil is now run off into vats and boiled up with about half its bulk of water; this removes any acid that may be adhering to the oil: the fire is then withdrawn, and in a short time the oil floats upon the water, and may be run off into casks ready for the market.

Other processes have been recommended for the purification of oils; as, for example, the filtration of them through animal or peat charcoal, or the exposure of them to the action of light, or to the chemical influence of a weak solution of chloride of lime; but all these processes are more or less difficult of management, and consequently they have given place to the more speedy and certain method of refining by means of oil of vitriol. It may, however, be stated that the filtration of oil through charcoal is a very effectual plan for removing bad colour or bad odour.

General Properties of Oil.—Every variety of fixed oil communicates a greasy stain to paper or cloth, and has an unctuous feel. It is also perfectly insoluble in water; and when mixed therewith, speedily rises to the surface. This shows that it is lighter than water; in fact, a bottle which, when full, holds 1000 grains of distilled water, will contain only 884 of sperm oil, or 965 of castor oil. These are the two extremes, for sperm oil is the lightest of all the fixed oils, and castor the heaviest. Chemists have applied the term *specific gravity* to these numbers; and as it is found that each oil has its own particular weight, specific gravity is made the means of discovering the nature and quality of any doubtful oil. The following table represents the relative weights or specific gravities of different fixed oils:—

Sperm	884	Cherry-stone	924
Tallow	900	Fish	924
Rape-seed	913	Cameline	925
Plum-kernel	913	Nightshade	925
Henbane-seed	913	Sunflower-seed	926
Colza	914	Hemp-seed	926
Ground-nut	915	Cocoa-nut	926
Olive	916	Walnut	926
Sessamum	916	Filbert	926
Almond	917	Anda	927
White mustard-seed	918	Horse-chestnut	927
Radish-seed	919	Cod-liver	928
Grape-seed	920	Seal	929
Poppy-seed	922	Linseed (new)	930
Whale (train)	923	Weld-seed	936
Black mustard-seed	923	Orange-seed	940
Walnut	923	Linseed (old)	960
Cucumber-seed	923	Castor	965
Tobacco-seed	923		

Most of the fixed oils are affected by the atmosphere—the oxygen of which they slowly absorb. In some cases the oil becomes thick; or if exposed in a thin layer, it dries. In this manner a skin is frequently formed over the surface of the oil; and if it be left for some time in a lamp, it will assume a jelly-like appearance. Other oils do not become so thick by exposure to the air; but they acquire an unpleasant smell, and get rancid. The former is the property of the drying, and the latter of the fat or unctuous oils. These changes are due to the action of atmospheric oxygen; indeed, Saussure found that a layer of nut-oil, one-fourth of an inch in thickness, absorbed as much as 145 times its bulk of oxygen in the course of eleven months, of which quantity 142 volumes were taken up during three months' exposure to the sun. It appears also that it is the carbon of the oil which undergoes oxidation; and, as it were, slowly burns, evolving carbonic acid. This change is always accompanied with an elevation of temperature; and hence it sometimes happens that rags or tow, or cotton, that have been smeared over with oil and then thrown aside as useless, have, in the course of a few days, generated heat enough to produce spontaneous combustion. Fires have frequently originated in this manner in warehouses and dockyards, where such materials have been allowed to accumulate. This points to the danger that is attendant on the careless and slovenly trick of throwing greasy rags and other such matters into out-of-the-way corners. Those oils which absorb oxygen with great facility, and thereby become thick, are not well suited for combustion in lamps, unless the lamp is cleaned out every day and a fresh wick adapted to it. The quick-drying oils are linseed, poppy, walnut, hemp-seed, and nut—all of which are employed by painters on this very account; while rape, colza, sessama or gingilie, cocoa-nut, grape-seed, cameline, sunflower, cotton, mustard, &c., only dry after very long exposure to the air; and sperm, olive, almond, seal, and whale oils are not much disposed to dry at all.

Heat and cold act upon the oils and produce changes in them which are more or less hurtful. In cold weather—that is, at a temperature below 32°—most of the oils become thick, from the congelation of their solid constituents; and we then find great difficulty in making the oil burn in a lamp. At a temperature of 600°, or thereabouts, the several fats begin to boil; and if the temperature be carried a little higher, the oil undergoes decomposition, and gives forth a most irritating and unpleasant vapour, which is called *acroline*. At still higher temperatures, the fixed oils are resolved into combustible gases, which burn with a very bright light and a sooty flame: indeed, the object of all the arrangements for the combustion of oil in lamps for illuminating purposes, is that of bringing the oil slowly into contact with the burning wick, so as to generate the gas in question, the supply of which ought to be duly apportioned to that of the air which consumes it. When oils are heated to near their boiling-point, they frequently become thick, and acquire an increased disposition to absorb oxygen. It is on this account that inferior drying oils cannot be employed for any length of time in a lamp, without closing the channels that lead to the wick; and hence it is found necessary to clean the lamp very frequently, or else to pour away the residue of the last consumption before fresh oil is supplied. The same circumstance leads to the stoppage of the pores of the wick, and finally to a total occlusion of all the fine capillary channels by which the oil ascends to the flame; so that a new wick and a clean lamp are indispensable to the perfect combustion of an inferior oil.

Although the fixed oils are not soluble in water, yet they combine [illegible] ry readily with fluids which contain alkaline matters, as soda or potash. In this wa [illegible] ey form white emulsions of the nature of soap; and the alkalies, or their carbon [illegible] be at all times resorted to for the purpose of cleaning out the half-gelat [illegible] a old lamps. Ammonia, also, or strong sal volatile, is a very effective [illegible] ving grease from the clothes.

Concentrated sulphuric acid acts on the fixed oils in the same way as it operates on the solid fats: it first combines with the fatty acids, and then with t [illegible] constituent to form composite acids, named sulpho-oleic, sulpho-margaric, sulpho-steric, and sulpho-glyceric acids. These are not permanent compounds, and have not, therefore, been isolated; but when they are treated with hot water, they are decomposed, and as the sulphuric acid separates, the other fatty constituents resolve themselves into four new acids—namely, metamargaric, hydromargaritic, metoleic, and hydroleic. The first two are solid, crystallizable, and partly volatile, while the last two are liquid and oily. Besides these changes, there are others effected by the action of the sulphuric acid on the sugar, mucilage, colouring matter, &c., contained in the oils; and these are so peculiar and characteristic, that they have been made the means of discovering the nature of a fixed oil. This fact was first recognised by Heidenreich of Strasburg, in

1841; but it has been greatly developed by the investigations of Penot, Marchand, and others. The mode of proceeding is as follows:—Put eight or ten drops of the oil on a white plate, and then let fall into the centre of the oil a single drop of concentrated sulphuric acid: in the course of a few seconds or minutes, the characteristic tints will be observed. Another mode of conducting the experiment is to stir the drop of acid so as to mix it with the oil. The following are the changes observed:—

(*a.*) With *olive oil* there is a yellow colour produced at the points of contact; this rapidly passes into orange, and at last into a bright chestnut-brown, while the surrounding parts of the oil gradually acquire a dirty gray, and finally a smoky tint; but there is never any shade of blue or lilac. If the mixture be stirred, it speedily becomes dirty-brown or brownish-gray.

(*b.*) *Poppy oil* immediately acquires a fine lemon-yellow colour, which soon becomes darker in some parts. The surrounding portion gradually assumes a rose tint, which speedily passes into violet, and then into a violet-blue. This requires a period of from half an hour to three-quarters, and finally the yellow colour becomes dirty-brown. If the oil has been kept for some months, or if it has been expressed by the aid of heat, it will then assume a greenish tint. When stirred it acquires a brownish-olive colour.

(*c.*) *Nut oil* produces almost exactly the same tints as olive oil, but it becomes brown more rapidly, so that within ten minutes it acquires a chestnut-brown colour, and the gray border changes into olive-green. If it be stirred, the oil clots and becomes dirty-brown.

(*d.*) *Castor oil* assumes a yellow tint, which slowly passes into grayish-red, and at last, after many hours, into purple-brown. When the oil is very old it becomes brown at once; and if the oil and acid be stirred, the tint is pale yellow, and then brown.

(*e.*) *Almond oil* produces nearly the same reactions as olive oil; but the surrounding tint is pale grayish, and the yellow has a greenish tint. If stirred it becomes dirty-green.

(*f.*) *Sessama*, *gingilie*, or *teal oil* assumes a yellowish colour, which in the course of a few minutes becomes orange, and then chestnut-brown, the surrounding oil acquiring, in the course of half an hour, a purplish-tint. If it is stirred it acquires an orange-brown colour directly.

(*g.*) *Ore*[illegible] *oil* takes on a yellow shade, which rapidly passes into brown, and then in[illegible] If stirred it becomes black almost immediately.

([illegible] *black and white mustard-seed* is first yellow, then rich yellow-orange, and [illegible] course of a few minutes, brownish-black, the surrounding oil being of a green[illegible] By stirring, the dark tint is brought out almost immediately.

(*i.*) *Linseed oil* becomes rich chestnut-brown almost immediately, and it soon coagulates, [illegible] into a hard, tenacious spot. When stirred it immediately thickens, and acquires a brownish-black appearance.

(*k.*) *Hemp-seed oil* presents nearly the same character as linseed, except that this oil assumes a greenish-yellow tint at the edges of the acid; and if stirred it acquires a greenish-brown colour.

(*l.*) *Cocoa-nut oil* acquires a pale purplish-brown colour, which gradually darkens; and when stirred it is first ochre-brown and then deep violet-brown.

(*m.*) *Refined rape-seed oil* assumes the same appearances as the last; and it is charred, as it were, by the acid.

(*n.*) *Fresh-drawn* or *raw rape-seed oil* becomes bright green; and then, after the lapse of ten minutes or a quarter of an hour, the tint deepens, and finally becomes olive-green or dirty greenish-brown; the surrounding edges retain a bright green colour. If the oil and acid be stirred, the tint is bluish-green, and at last olive-green.

(*o.*) *Oleic acid* changes into a sepia brown, which at length darkens almost to a black.

(*p.*) *Neat's-foot oil* becomes yellow, and then after some time brownish. If stirred, it changes into a dirty-brown at once.

(*q.*) *Whale* or *train oil* acquires a reddish-brown colour, with the edges of a violet tint; and if stirred it passes into dark violet-brown, like that of the lees of wine.

(*r.*) *Cod* and *other liver oil* instantly changes to a rich violet, with the edges of a carmine colour; in the course of a few minutes this passes into orange, and, finally, into dark-brown. When stirred, the violet tint is very remarkable, but very transient.

(*s.*) *Seal oil* assumes a yellow colour, which passes into rich orange and then into blackish-brown, having a number of purple spots about the mixture. When stirred, it acquires a lively yellow tint, which soon changes to orange-brown.

If the acid is diluted with one-third its bulk of water, the reactions are slower, and the effect, in some cases, is more marked. With such a mixture, olive, almond, and castor oils show but little action; while poppy, orange, and mustard become dirty-brown; gingilie, yellowish with a pink border; linseed, brown; rape, green; cocoa-nut and refined rape, pale purple-brown; sessama, lavender; oleic acid, dirty-brown; sperm, pale lavender; cod-liver, rose, passing into rich violet and then into brown; common whale, black-brown; seal, dirty-brown; and tallow-oil, blackish-brown.

Mixtures of the above-mentioned oils give reactions which are compounded of the preceding; and thus the fraud of adulteration may be easily detected.

Another reaction which has been noticed during the admixture of the oil with concentrated sulphuric acid, is that of a great elevation of temperature; and, as each oil produces its own amount of heat, M. Maumené has proposed that this reaction should be used as a means of discovering the quality of an oil. Maumené's results have been confirmed in the laboratory of Professor Fehling by Faisst and Knauss, who state that when 225 grains of oil are quickly mixed in a thin glass vessel with 75 grains of the strongest sulphuric acid, the following are the number of degrees raised by different oils:—

Olive oil . . .	68° Fah.	Rape oil . . .	100° Fah.
Lucca oil . . .	72° "	Poppy oil . . .	127° "
Almond oil . .	72° "		

With an acid of 90 per cent. the rise is:—

Lucca oil .	54° Fah.	Rape oil .	67° Fah.	Linseed oil .	133° Fah.

Mixtures of these oils produce intermediate results.

Aqua-fortis, or *nitric acid*, acts with more or less energy on the fats, and converts them into other acids; one of which, namely, suberic acid, is a very constant product. But the most remarkable change is brought about in all the fats by means of *nitrous acid*, or a solution of *nitrate of mercury*. Either of these compounds will cause the fat oils to become solid; the oleine of the oil being converted into a semi-transparent jelly-like mass, named *elaidine*. This curious change is effected in olive, almond, rape-seed, hazel-nut, and other non-drying oils; but the drying oils, as linseed, hemp-seed, walnut, poppy, &c., are not affected by these compounds. This circumstance, and the facility with which the change is brought about, offer a means of distinguishing one kind of oil from another. M. Poutet recommends the following method for the application of this test:—Dissolve six parts of mercury in seven and a half parts of nitric acid (sp. gr. 1·35); add two parts of this solution to ninety-six parts of oil, and shake the mixture every now and then for half an hour or so. If the experiment be made on pure olive oil, it will congeal in the course of seventeen hours in summer, or four hours in winter. Other vegetable oils do not combine so quickly with nitrate of mercury; and the mixture either remains fluid, or else the olive oil congeals, and the other oil separates into a distinct layer. If the oil has been adulterated with animal fat, the mixture congeals in five hours, whilst the olive oil floats on the surface and may be decanted. MM. Boudet and Fauré have shown that this change is brought about by the *hyponitrous acid* contained in the nitrate of mercury. They therefore recommend a solution of that acid in aqua-fortis—*common nitrous acid* does very well for the purpose; and they say that each of the fat oils takes its own time to solidify, and develops its own colour. When one part of hyponitrous acid is dissolved in nine of aqua-fortis, and then added to a hundred parts of oil, the colour produced, and the times of solidification, are as follow:—

Olive oil	becomes	greenish-blue,	and solidifies	in	73	minutes.
Almond	,,	dingy-white	,,	,,	160	,,
Filbert	,,	greenish-blue	,,	,,	103	,,
Acorn	,,	lemon-yellow	,,	,,	40	,,
Castor	,,	golden-yellow	,,	,,	603	,,
Colza	,,	yellowish-brown	,,	,,	2400	,,

Oil of poppies retards the solidifying effect, and this to so great an extent, that when present in either of the above, in no larger portion than one per cent., it delays the action for forty minutes.

A mixture of *equal parts of nitric and sulphuric acids* also affects the coloration of the fixed oils; and this has been shown by M. Behrens, as well as by MM. Guibourt and Reveil, to be a good means for detecting the adulteration of oils. About 150 grains of the mixed acids are added to a like quantity of the oil, and the colour, which is instantly produced, is as follows:—

Oil of Sessama	dark grass-green.
,, Olive	light yellow.
,, Linseed	brownish-red.
,, Almond	peach-blossom.
,, Castor	little changed.
,, Colza	reddish-brown.
,, Poppy	brick-red.
,, Gingilie	rich orange-brown.
,, Orange-seed	rich chestnut-brown.
,, Mustard	orange-brown.
,, Rape-seed (raw)	orange-red and then dirty green.
,, ,, (refined)	yellow-red and then purple-brown.
,, Cocoa-nut	pale orange-red.
,, Sperm whale	orange.
,, Seal	orange-brown.
,, Cod-liver	pinkish-violet.
,, Tallow	dirty brown.
,, Neat's-foot	,, ,,

M. Behrens states that when olive oil is mixed with a fourth part of its weight of sessama oil, it takes a beautiful green colour; but Guibourt and Reveil assert that it will discover one-tenth part of sessama in oil of olive.

Other oxydising agents, as *chromic acid*, or *a saturated solution of bichromate of potash, in oil of vitriol*, also act in a very characteristic manner on the fixed oils. This fact was first observed by M. Penot, who employed a single drop of the latter solution with twenty drops of oil, stirring them together on a white plate. The following are the effects produced:—

Almond oil . .	becomes	yellowish in small lumps.
Hemp-seed oil .	„	yellow in clots on a green ground.
Rape-seed oil .	„	„ „ „ „
Poppy oil .	„	„ „ „ „
Ditto (cold-drawn)	„	„ „ white ground.
Castor oil . .	„	slightly green.
Linseed oil .	„	brown clots on a white or greenish ground.
Nut oil . .	„	brown clots.
Olive oil . .	„	brown.
Cod-liver oil .	„	dark red.
Whale oil . .	„	brownish-red clots on brown ground.
Tallow oil . .	„	reddish-brown.
Neat's-foot oil .	„	brownish red spots on brown ground.

The illuminating power of different oils varies with different circumstances, as with the temperature of the room, the size and form of the wick, and the freedom with which the oil is supplied to the flame; so that it is difficult to arrive at anything more than an approximation to the value of different oils as illuminating agents. Count Rumford estimated the relative illuminating power of different oils when burnt in Argand and in common lamps, thus—the numbers being the weights consumed to get an equal amount of light:—

Good wax, well-snuffed	100 grains.
Olive oil in an Argand lamp	100 „
Olive oil in a common lamp	129 „
Rape oil „ „ „	125 „
Linseed oil „ „ „	120 „

From some experiments which have been conducted for the purpose of arriving at an approximation to the relative value of different oils, we have drawn up the following table, which represents the proportions of oil to be consumed in order to obtain a light of given value—namely, that of thirteen sperm candles, each consuming 120 grains per hour. In these experiments the same lamps were used for each of the oils, and the wick was in each case of precisely the same description; a new wick being employed for each experiment. The consumption of oil in the Argand ranged between 316 and 378 grains per hour, and that of the common lamp between 87 and 123.

	Argand Lamp.	Common Lamp.
Tallow . . .	1008 grains.	1300 grains.
Sperm . . .	1029 „	1751 „
Train . . .	1067 „	1941 „
Olive . . .	1080 „	2014 „
Seal . . .	1107 „	1892 „
Sessama . . .	1113 „	1776 „
Poppy . . .	1119 „	1660 „
Refined rape . .	1134 „	1881 „

	Argand Lamp.	Common Lamp.
Refined linseed	1231 grains.	2376 grains.
Raw rape	1236 "	1940 "
Brown rape	1343 "	1827 "
Mustard-seed	1354 "	2058 "
Fish	1362 "	1976 "

From this it will appear that there is no direct relation between the illuminating power of the oil and its consumption; for in some cases the oil burns better in the common lamp than it does in the Argand, and *vice versa:* showing that the illuminating power is modified by circumstances. This table has been constructed on the scale of thirteen sperm candles of standard value, because they represent the light of an Argand burner consuming five cubic feet of coal-gas per hour.

VARIETIES OF OILS EMPLOYED FOR ILLUMINATING PURPOSES.

Animal Oils.—(*a.*) *Sperm oil.*—This, as we have already said, is the fluid portion of the head-matter which is removed from the cranial cavity of the spermaceti whale (*Physeter macrocephalus*). The oil is separated from the spermaceti by means of cold and pressure; and after having been purified by means of a little weak sulphuric acid, or alkaline lees and water, it is sent into commerce. Sperm oil is of a pale colour; it has but little odour, and it shows no disposition to congeal in cold weather, or to resinify on exposure to the air; it is, therefore, well suited for illuminating purposes.

(*b.*) *Common whale oil*, or, as it is sometimes termed *whale train-oil*, is derived from several species of whale; as the common whales (*Balænæ*), the finned whales (*Balænopteræ*), and the narwhales (*Monodons*). Most of the oil consumed in this country is furnished by the common Greenland whale, the *Balæna my sticetus*, large numbers of which are annually captured by the whalers of England and America in several of the Arctic Seas. They are taken in the Greenland seas; in Davis' Straits; along the coasts of Spitzbergen, Iceland, and Norway; off Labrador; in the Gulf of St. Lawrence; around Newfoundland; in Baffin's and Hudson's Bays; and in the seas northward of Behring's Straits. The balæna is also found in more congenial climates, as on the coast of Ceylon, and in the China Sea.

In the early days of whaling, when the animal was found in great numbers immediately around the shores of Spitzbergen, the Dutch formed a settlement on that island, and performed there all the operations of preparing the bone and extracting the oil. They gave the name of Smeerenberg (from *smeeren* to melt) to their settlement; and to so flourishing a state did the fishery arrive, that, during the busy season, every species of luxury could be obtained at the village, although it was situated within a few degrees of the pole. This was the condition of things towards the close of the seventeenth century. But it appears from a narrative of the voyage of Ohthere the Dane, given by King Alfred in his translation of Orosius, that the pursuit of the whale was practised by the people of Norway at least as early as the ninth century. We have no account, however, of the way in which the animal was captured, nor are we informed as to the object of the pursuit—whether it was for mere sport, or for some useful purpose. It is very probable the business of hunting the whale was not carried out upon any systematic plan, but was confined to such accidental encounters as opportunity offered. As early as the twelfth century, the inhabitants of the coast surrounding the Bay of Biscay were undoubtedly engaged in the capture of the whale for commercial purposes; and they are generally regarded as the founders of this species of enterprise. At first their operations were confined entirely to the neighbouring bay; but as the whale became scarce, the Biscayan mariners extended their search farther and farther from their shores, until they reached the coasts of Iceland, Greenland, and Newfoundland. "Thus," says Mr. Dewhurst, "was commenced, in the course of the sixteenth century, the northern whale-fishery, as pursued in modern times. In 1594 the English made their first whaling voyage; and four years afterwards the merchants of Hull fitted out several ships for the purpose: about the same time the Dutch were tempted to engage in the trade; and soon afterwards the Hamburgers, the French, and the Danes were occupied in the same pursuit."

The whale is captured by means of harpoons, and when it is dead it is drawn to the side of the ship and flensed or cut up. This is effected by means of spades and powerful knives, the blubber being cut into cross pieces of about half a ton each, which are hoisted on deck, and then subdivided into small strips, which are forced into the bung-holes of the storing casks. The blubber is the true skin of the animal; and it consists of a net-work of intersecting fibres, which enclose the liquid fat. It encompasses the whole of the body: its thickness varying from eight to twenty inches, though one foot is about the average; and a single whale will yield from twenty to eighty tons of it. The lips of the animal furnish the best kind of blubber; and they weigh from one and a-half to three tons each. The quantity of oil so obtained amounts to about three-fourths of the entire weight of the raw blubber.

Formerly, it was the custom to extract the oil from the blubber at the places where the whales were caught, but now this process is effected after the fat arrives in this country. The operation is thus managed:—The half-putrefied fat is thrown into vats which have a wire grating at the bottom. The tissue is then broken up by pressure, and the oil runs out into a reservoir, which is placed below the vats: that which remains behind is called *finks*. After the oil has settled for two or three days, it is poured off into another vessel and heated to a temperature of 225°. This causes the albuminous matter to coagulate, which, with the other impurities, soon subsides to the bottom of the boiler. The fire is now withdrawn, and water is poured into the vessel, in order that the dregs may be more easily separated from the oil, and may not stick to the bottom of the boiler. After standing for some time, the oil becomes clear, and then it is run off into casks. Another mode of extracting the oil is to boil the blubber with water, and to skim off the oil as it rises. The oil may also be obtained by allowing the blubber to putrefy, and thus to release the fluid fat from the cells in which it is contained. In this manner, by suspending the blubber in bags over casks, the oil gradually drips out, and is collected.

We have already said that the train oil of commerce is chiefly derived from the common Greenland whale (*Balæna mysticetus*); but when this creature is scarce, another species of balæna—namely, the *Balæna Icelandica*, or nord-caper—is sought for; and under certain circumstances the different species of finned whale, as the *Balænoptera gibbar*, *boops*, *rorqual*, &c., and even the *Monodons* or *narwhales*, may be made to yield train-oil. It is not often, however, that the whaler has an opportunity of capturing these creatures; for they are so swift and shy, that there is great difficulty as well as danger in approaching them. Occasionally they are cast ashore on the northern and western coasts of Europe: and then they become a source of great profit from the quantity of oil which they yield. Some idea may be formed of the value of these animals by the following fact:—In the month of August, 1827, a large specimen of the *Balænoptera rorqual* was found floating off the port of Ostend. It was towed into the harbour by some fishermen;

and when cut up, it yielded 40,000 lbs. or 4000 gallons of oil. The specimen measured ninety-five feet in length, and weighed about 240 tons.

Lastly, it may be stated that the several species of *dolphin* furnish abundance of oil. They belong to the whale tribe, and inhabit the seas of all latitudes; for they are found in the Arctic Ocean, the Mediterranean, the Gulf of Messina, the Adriatic, and on the coasts of China: in many of which places there are large establishments for their capture, in consequence of their furnishing an excellent oil for illuminating purposes. To this order of animals belong the common porpoise (*Phocæna vulgaris*), the round-headed porpoise or ca'ing whale (*Phocæna melas*), and the white whale (*Phocæna leucas*); all of which yield oil in considerable quantity. The common porpoise is captured by the inhabitants of the western islands of Scotland, where it abounds; and we are told that about eight gallons of oil are obtained from each individual. The round-headed porpoise is taken in the Shetland Islands, the Orkneys, and in Iceland; and the white whale in several localities on the shores of the North Sea.

The oil obtained from these sources, when properly purified, is very little inferior to sperm oil: it does not clog the wick or congeal in cold weather, and it burns with a clear white flame, which is tolerably free from smell. About 20,000 tons of whale oil and spermaceti are annually imported into this country.

(*c.*) *Seal oil* is procured from several species of phocidæ. The common seal (*Phoca vitulina*) is captured in large numbers on the shores of Newfoundland: indeed, we are informed that during a good year, hundreds of thousands are taken in that locality, for the sake of the oil which they yield. They are also killed on the northern coast of Scotland, in the Orkneys, Zetlands, and on the shores of Greenland. To the inhabitants of the last-named locality the seal is invaluable; for it furnishes them with food, raiment, and oil. The animal is usually captured with spears or harpoons, and sometimes it is shot. As soon as it is dead, the skin is stripped off, and then the fat is removed and boiled down in copper or iron vessels. Seal oil, like the preceding, is not much disposed to thicken; and hence it is well suited for combustion in lamps.

(*d.*) *Walrus oil* is obtained from the morse or sea-cow (*Trichecus Rosmarus*), many of which are annually destroyed at Spitzbergen and elsewhere, for the sake of the skin, oil, and teeth. We do not receive the oil into commerce in this country, and consequently have litte or no opportunity of testing its value; but it appears that its qualities are not inferior to those of the last-mentioned oil.

(*e.*) *Fish oils* are extracted from the bodies and livers of fish. As examples of the former, we may mention the oils obtained from the herring (*Clupea harengus*), pilchard (*Clupea pilchardus*), and sprat (*Clupea sprattus*): all of which are procured by submitting the fish to great pressure at the time that they are undergoing the process of salting. Of the latter may be mentioned the oils of cod (*Morrhua vulgaris*), ling (*Gadus molva*), skate (*Raia batis, &c.*), burbot (*Lota vulgaris*), torsk (*Brosmius vulgaris*) &c. The oil is obtained by placing the livers in a tub which has a perforated bottom covered with small branches of trees. As the livers putrefy, the oil drips out, and is caught in a vessel placed underneath. At other times the oil is extracted by boiling the livers in an iron pot, and then squeezing them in linen bags. Cod-liver oil is not much used for purposes of illumination, as it is a valuable remedy for the cure of many diseases; but the oil of ling is extensively prepared by the poor of the Orkneys and western islands of Scotland, where it is employed as a common lamp-oil. All these oils are somewhat of a drying nature, and therefore become thick after a time; besides which, unless great care has been taken in their preparation, they are sure to have a most unpleasant fishy or putrid odour.

(*f.*) *Lard oil, and the oleine from tallow and other animal fats*, is obtained from the solid fats by slightly warming them and then submitting to pressure. This oil is apt to deposit solid matter in cold weather, and thus to become thick; but the properties of the oil are otherwise very good; and consequently it is well suited for combustion in lamps. The *oleic acid*, which is procured during the manufacture of stearic and margaric acids for candles, is not fit for illuminating purposes; for although it gives out a very good light during its combustion, yet it is so apt to clog the wick from the impurities which it contains, that in the course of a very short time the lamp ceases to burn. Were it not for this, oleic acid might be extensively employed as an illuminating agent.

Vegetable Oils.—(*a.*) *Olive oil.*—This is furnished by the fruit of *Olea Europea*, of which there are two varieties—namely, the *longifolia* of France and Italy, and the *latifolia* of Spain. The olives are gathered as soon as they are ripe, and this takes place early in November. In France, where the best oil is prepared, the fruit is bruised in a mill directly it is gathered; it is then wrapped in a sort of matting and submitted to pressure. The oil which runs out is called virgin oil, and is kept separate for table and dietetical purposes. The cake is removed from the press, broken up by hand, moistened with boiling-water, and re-pressed; in this manner a second quality of oil is obtained, which on standing, separates from the water with which it is mixed. The cake that is left from this operation is called *grignon*, and generally it is set aside to dry in order that it may be used for fuel; but sometimes it is submitted to fermentation, then wetted with boiling-water and pressed a third time, by which means a third quality of oil, called *gorgon*, is procured, which is used for lamps and machinery.

In Spain the olives are allowed to ferment for a period of ten days or a fortnight before they are crushed and pressed. In this way a larger supply of oil is obtained, but the quality is very inferior to that prepared from the fresh nut. One of the reasons why this delay takes place, is, that there are not sufficient presses in the oil districts to perform the necessary work; and hence the several growers are obliged to wait their turn, and keep their olives ready for the mills. But within the last few years considerable improvement has been effected in this respect by the introduction of hydraulic presses; and now a large portion of the oil obtained from Spain is equal, or nearly equal, in quality to that of France and Italy.

The machinery employed by the Neapolitan peasants in the preparation of Gallipoli oil, is of the rudest kind. The olives are allowed to ripen to the fullest extent on the trees; and as they fall off they are collected by women and children, and carried to the mill. The oil which is expressed is put into sheep or goat-skin bags, and conveyed on the backs of mules to Gallipoli, where it is allowed to clarify by standing in cisterns which are cut out of the rock on which the town is built. When it has become sufficiently clear by the deposition of mucilage, water, and other impurities, it is run off into skins, and conveyed to oil-basins which are situated near to the sea-shore. From these it is put into casks, and exported.

According to Sieuve, olives furnish about thirty-two per cent. of oil—twenty-one of which come from the pulp (or pericarp) of the fruit, four from the seed, and seven from the woody matter.

In whatever way the oil is obtained, it must be clarified and freed from mucilage, &c., before it is fit for use. This is usually accomplished by allowing the oil to stand in a warm place for a fortnight or three weeks, during which time it deposits impurities, and becomes clear. It may also be refined by heating it for a short time with a weak solution of potash or soda, and then allowing it to stand; or it may be deprived of its acid congealable matter, by exposing it for some time to the action of a piece of lead—the bottle containing the oil and the lead being placed in a window, or other place where it will receive the direct rays of the sun. In this way the oil used by watchmakers and machinists is refined.

The amount of olive oil annually imported into England is about eighteen or twenty thousand tons. In the year 1849, it amounted to 16,864 tons—of which 9,661 tons came from Naples and Sicily (Gallipoli oil); 2,237 from Malta; 1,712 from Turkey; 832 from Tuscany; 753 from Spain; 506 from the Ionian Islands; 368 from Morocco; 333 from Sardinia; and 462 from France and elsewhere. The imports into Liverpool during the year following were 4,815 tons from Gallipoli; 2,330 from Barbary; 2,100 from the Levant; 762 from Corfu; 15 from Leghorn; and 8 from Palermo. The best variety of olive oil is called Florence oil, which is the produce of Aix, in France; while the worst is the Spanish.

In this country the price of olive oil renders it too costly for lamps; but in Italy, Spain, and France, it is extensively employed for such purpose. It burns with a clear white light, and does not emit any unpleasant odour; besides which, it is not a drying oil, and is therefore not likely to clog the wick. When it is adulterated with poppy, nut, or sessama oils, its properties are very much deteriorated.

(*b.*) *Almond oil* is extracted from the kernels of the common almond (*amygdalus communis*), of which, as in the case of the olive, there are two varieties; namely, the sweet (*dulcis*) and bitter (*amara*), both of which yield the oil of commerce. The almonds are agitated in bags, so as to separate a portion of their brown skin, then crushed in a mill, and, after being folded in canvas-bags, they are subjected to pressure between cast-iron plates. That which runs over first is the best. The residue is then heated and again pressed, by which means an oil of inferior quality is procured. When first obtained, the oil is thick and discoloured; but by repose in a warm place, or by filtration through paper or sand, it becomes clear. Almonds yield from twenty-two to twenty-four per cent. of oil. It is too expensive for lamps, though its flame is very brilliant, and its other qualities are remarkably good.

(*c.*) *Rape oil* is extracted from the seeds of several species of brassica (the cabbage and turnip tribe), as the *Brassica oleracea*, *campestris*, *napus*, &c.; all of which are cultivated in this and other countries for the oil which they yield. In France a very superior rape oil, termed *colza oil*, is obtained from a variety of *Brassica campestris*, named *oleifera*. In every case the oil is procured by crushing or grinding, and pressing the seed in the way already described, and it is refined by the addition of one or two per cent. of sulphuric acid. The seeds yield from twenty-eight to thirty per cent. of oil.

Most of the rape oil employed in this country is expressed here. Occasionally we receive small shipments of the oil from Belgium, France, and the East Indies; but by far the larger proportion is obtained from the seed itself, of which we import large quantities. In the year 1850 we received as much as 29,490 quarters of the seed from different places: of these, 13,126 came from the East Indies; 3,235 from Russia; 3,092 from Denmark; 2,872 from the Hanse Towns; 2,480 from Austria; 1,637 from Greece; 1,280 from Wallachia and Moldavia; 645 from Prussia; 201 from Holland; and 922 from France and other places. Mr. Brotherton, who is a large oil-presser, states, that good English-grown rape yields the best kind of oil; and he recommends this fact to the notice of agriculturists, saying that as much as five quarters of seed, worth fifty shillings a quarter, may be obtained from an acre of land.

Rape oil is extensively used for illuminating purposes, both here and on the continent: in fact, it is now the usual lamp-oil of commerce. Its properties are but little inferior to those of sperm; and the only objection that can be urged against it is, that after it has once been heated in the lamp it is apt to thicken and to clog the wick. Colza oil is generally consumed in the Carcel or French lamp; but it has no very great advantages over the commoner kinds of rape oil. The crude or raw oil is not suited for such purposes, on account of the mucilage which it contains: it is of a greenish-brown colour, and has somewhat the odour of linseed oil; but when it is refined it loses both of these objectionable properties, and becomes as pale and limpid as sperm.

(*d.*) *Cocoa-nut oil* is the produce of the *Cocos nucifera*, or common cocoa-nut palm; the fruit of which is decorticated, crushed, heated, and pressed. We have already stated that the oil is imported into this country in a buttery or tallow-like condition; and that after submitting it to pressure between warm plates, the liquid oil runs out, leaving the cocinine or cocoa-nut stearine for the manufacture of candles. The elaine or oleine of *palm oil* may be obtained in a similar way; and both of the oils may be purified by means of common sulphuric acid. Cocoa-nut oil has rather a pleasant odour, and it burns exceedingly well in lamps, provided it is not exposed to too low a temperature; for it is apt to congeal by cold.

(*e.*) *Sessamum or Gingilie oil* is procured from the *Sessamum orientale*, of which there are several varieties cultivated in India for the oil which they yield. These are the *suffed-til* or white-seeded variety; the *kala-til* or party-coloured; and the *tillee* or black. It is from the latter that the oil is chiefly obtained. A large quantity of the oil and seed is imported into this country, and into France for the purpose of adulterating other oils; but in India it is used very extensively as an article of diet, and also for lamps. The oil is extracted and refined in the usual way.

(*f.*) *Ground-nut oil* is obtained in large quantity from the ground-nut or seed of the Bhoe moong (*Arachis hypogæa*), a plant that is pretty extensively cultivated in various parts of India. The seeds furnish about forty-four per cent. of a clear pale-yellow oil, which is largely used as food and for lamps. Two varieties of the plant are cultivated in Malacca,—namely, the white seed and the brown, both of which yield a very good oil. About eighty or ninety tons of this oil are imported into this country every year.

(*g.*) *Common nut oil* is derived from two sources—namely, the *Corylus avellana*, or common hazel-nut; and the *Juglans regia*, or common walnut. The former produces about half its weight of oil, and the latter about one-third. The oil is not much used for lamps on account of its energetic drying properties: indeed, it is more apt to resinify and clog the wick than linseed; but it is largely employed for adulterating other oils.

(*h.*) *Poppy oil* is procured from the seeds of several species of poppy, as *Papaver somniferum*, *bracteatum*, *orientale*, &c. The plant that yields the largest amount of oil, and which is usually cultivated for this material, is a variety of the *somniferum*, named *nigrum*, from the black colour of the seeds. Large quantities of this oil are expressed every year for the purpose of adulterating other oils. It is clear, sweet, limpid, and almost colourless; but the great objection to its use as a lamp-oil, is its disposition to dry.

(*i.*) *Linseed oil* is extracted from the seeds of the flax plant (*Linum usitatissimum*), which yield from twenty-two to twenty-seven per cent. of oil. If the seeds be crushed and pressed at an ordinary temperature, they yield not more than eighteen or twenty per cent.; but the oil is of a pale colour, and is thought by some to be of superior quality to the hot-drawn. A large quantity of linseed is cultivated in this country, but the great bulk of the seed used by the oil-presser is imported. In the year 1850, as much as 626,495 quarters were received here; and of these 482,818 came from Russia; 87,273 from Prussia; 26,142 from the East Indies; 17,517 from Egypt; 7,734 from Holland; 1,476 from Naples; 1,153 from the Hanse Towns; 910 from Wallachia and Moldavia; 870 from Sweden; 268 from Norway; 40 from Austria; 37 from Denmark; and 262 from other places. The seed is crushed, ground, and pressed in the usual way; and the oil is refined by means of dilute sulphuric acid. Linseed oil is not usually burnt in lamps, on account of its drying properties; but if the wick be changed every day, and no more oil is placed in the lamp than is necessary for one night's consumption, it will be found to burn very well, and to give a very clear light. By boiling or heating, it acquires increased consistence, and is then more apt to dry.

(*k.*) *Hemp-seed oil.*—This oil is produced from the Indian hemp (*Cannabis sativa*), the seeds of which yield about one-third their weight of oil. The oil has a disagreeable smell, and is not much employed for illuminating purposes, except by the poorer classes of India.

(*l.*) *Cameline or Dodder oil* is extracted from the seeds of the *Camelina sativa*, a plant that grows abundantly in Canada, where the oil is used as a common lamp-oil. It is also employed for the same purpose in several parts of Germany.

(*m.*) *Cotton-seed oil* is thought to be as good as rape for lighting purposes: indeed, small quantities of the oil have been expressed for several years past and used in this way; but the value of the material has not been fully realized until within the last year or two. At the Exhibition of 1851, specimens of the oil and cake were shown by Mr. Burn of Edinburgh, and by M. De Géminy of Marseilles, to both of whom prize-medals were awarded. It appears that as early as 1785 the importance of this material was perceived by the Society for the Encouragement of Arts and Commerce, for they offered a prize for its manufacture on a large scale; but it does not seem to have been taken up extensively, perhaps because of the difficulty in purifying the oil. It has, however, been extracted for some time in India, America, and Egypt. Of late years the oil has attracted attention, and means have been devised for its purification. This is of interest, because very large quantities of cotton-seed are destroyed every year: in fact, more seed is always produced than is required for the next year's crop, and hitherto this excess has been thrown away as useless. At present it is exported to this country or to France, where it is crushed and pressed. Mr. Burn of Edinburgh, and M. De Géminy of Marseilles, have each large mills for the expression and purification of the oil. When first expressed it has a dirty-brown colour; but by rectification with sulphuric acid, it becomes clear, and assumes a pale amber tint, in which condition it is well suited for combustion in lamps. The botanical name of the plant which furnishes the seed is *Gossypium herbaceum*. It is cultivated in India, Syria, Asia Minor, along the Mediterranean, and in America.

(*n.*) *Mustard Oil.*—This is procured from the dross or siftings of black and white mustard-seed (*Sinapis alba* and *Sinapis nigra*), both of which are cultivated very extensively in this and other countries, for the manufacture of mustard-flour. The siftings furnish about forty per cent. of a dark-brown oil; the seeds themselves yield from eighteen to thirty-six per cent. In India an excellent oil, called *shersha*, is expressed from several species of *sinapis*, as the *toria*, *glauca*, *nigra*, &c. All these varieties of mustard oil are very dark-coloured when first expressed, and they have the peculiar pungent odour of mustard. Both of these properties are, however, removed by the process of refining; and then the oil may be used in the place of rape or colza for illuminating purposes. Usually the oil is employed for the adulteration of the latter.

(*o.*) Besides these oils, many others are employed in various parts of the world for the purpose of giving light; thus, the oil of plum-stones (*Prunus domestica*) and of raisin-stones, or wine-stones (*Vitis vinifera*), are used in Spain, Germany, and France. The oils of belladonna-seed (*Atropa belladonna*), tobacco-seed (*Nicotiana tabacum et rusticum*), and henbane-seed (*Hyosciamus niger*), are used in Swabia and Wurtemburg. Oils are also extracted from the beech-nut (*Fagus sylvatica*), sunflower-seed (*Helianthus annuus*), weld-seed (*Reseda luteola*), orange-seed (*Citrus aurantium*), cucumber-seed (*Cucurbita pepo*), &c.; and in India there are numerous plants which yield abundance of oil that is well suited for illuminating purposes. Among these may be mentioned *ramtil oil*, or, as it is sometimes named, *teel oil*, from several varieties of *Gurzotia*, as *Gurzotia oleifera* and *Abyssinica*, both of which yield about eighty-four per cent. of oil that is very similar to sessamum oil; *Poon-seed oil*, or *Pinnacottay oil*, from the seeds of *Calophyllum inophyllum*, which furnish about sixty per cent. of it; *Napala oil*, from the seeds of *Jatropha curcas; Mulu unnay oil*, from the seeds of *Argemone Mexicana; Cheeroojee oil*, from the fruit of *Chirongia sapida*, or *Buchanania latifolia;* oil of *Kossumba*, or *Koosm oil*, from the seeds of the safflower (*Carthamus tinctorius*), which yield about twenty-eight per cent. of it; *Kanagu nune*, or *Kurrunj oil*, from the seeds of *Pongamia glabra*, or *Galedupa arborea; Mooncela oil*, from the seeds of *Dolichos biflorus*(?); *Caju apple oil*, from the seeds of *Anacardium occidentale; Lambolee oil*, from the seeds of *Bergera koenigii; common jungle oil*, from the seeds of *Ricinus communis;* and several other varieties, the sources of which are not well known. Many of these oils are admirably well suited for combustion in lamps; and if there were a sufficient demand for them, they might be furnished to commerce in considerable quantity. "The knowledge of this circumstance," say the jurors, in their report on the products of the Great Exhibition, "is of great practical value, because, not only is it possible that by the introduction of improved machinery, or by increased facilities of conveyance, their price may be reduced; but the very existence of such substances tends to equalize the market value of those oils now generally employed. And should, at any time, accidental circumstances cause the price of the latter to advance, these substances would then be most advantageously introduced, and would, probably, ere long, altogether supersede the oils in the place of which they had been originally imported."

Volatile Oils.—(*a.*) *Oil of turpentine or camphine* may be obtained from the oleo-resinous exudation of various species of pine, larch, &c., as the Scotch fir (*Pinus sylvestris*), the cluster pine of Bordeaux (*Pinus pinaster*), the swamp pine of America (*Pinus palustris*), the frankincense pine of Virginia (*Pinus tæda*), the silver fir of Germany, Siberia, and Switzerland (*Abies picea*), the common larch of the Continent (*Larix Europæa*), and the turpentine pistacia of Syria and Greece (*Pistacia terebinthus*). The oleo-resin is imported into this country under the names of common turpentine, Bordeaux turpentine, Strasburg turpentine, and Venice turpentine. The first of these yields the great bulk of the turpentine of commerce; it is the produce of the *Pinus palustris*, and perhaps also of the *Pinus tæda*. It is chiefly imported from the United States of America; from which locality, in 1849, we received as much as 412,000 cwts. The method which is generally adopted for procuring this oleo-resin is as follows:—The tree is selected, and a hollow is cut into it, a few inches from the ground; the bark is then removed for a space of eighteen or twenty inches above the hollow; and for several months—namely, from March to October—the turpentine flows from the divided sap-vessels into the excavation. At convenient times the semi-fluid matter is scooped out, and put into casks; and when these are full, they are sent away for exportation.

Volatile oil of turpentine is procured from the oleo-resin by distilling the latter with a due proportion of water. The turpentine and water come over together, forming a milky liquor, which on standing, separates into two layers, of which the turpentine is the uppermost. These are easily decanted or poured off one from the other; that which remains in the still is resin. Common American turpentine yields from fourteen to sixteen per cent. of spirits.

The turpentine which is thus obtained is not sufficiently pure for combustion in the camphine lamp, for it contains a small proportion of resin, which is very apt to clog the wick. This impurity is very easily removed by a second distillation, and the product which is thus obtained is sent into commerce under the name of *camphine.* It is a colourless, limpid, and very inflammable liquid, that burns with a remarkably sooty flame. Its specific gravity is 870, and it boils at a temperature of 314° Fah.; though, if water be present, it will distil at as low a temperature as 212°. Turpentine freely absorbs oxygen from the air, and is converted into an oleo-resin. In the course of four months it will take in about twenty times its bulk of atmospheric oxygen. The change which is thus produced in the liquid renders it unfit for combustion in the camphine lamp, in consequence of the resinous oxide having a tendency to clog the wick. To remedy this evil, the liquid must be re-distilled, and the camphine should be preserved in well-corked vessels.

The light that is emitted from turpentine when it is properly burnt is remarkably vivid and white; in fact, the illuminating power of camphine is nearly twice as great as that of sperm oil; and if it were not for the liability of the combustible to evolve smoke, it would be one of the most valuable of modern illuminating agents. This, indeed, is the great objection to its use; for it is found that ever so little mismanagement of the flame causes the production of a cloud of blacks, which settle upon the furniture and dress, and damage them irreparably. To obviate this as far as possible, the chimney of the camphine lamp is made very tall, and thus a strong current of atmospheric air is secured to the flame.

A mixture of turpentine and alcohol has been used in France for some time past, under the name of "*Eclairage au Gaz Liquide.*" The lamp which is employed for the combustion of this material was originally contrived by Lüdersdorff; it is called a vapour-lamp, because it is constructed so as to convert the volatile liquid into vapour, which burns as it escapes through a number of fine orifices. By diluting the turpentine with alcohol, its liability to smoke is considerably diminished; but still there is a large quantity of soot evolved when the mixture is burnt in an open lamp without a glass. The French liquid has a very peculiar odour · it is clear and limpid like water, and has a density of 823. Its boiling point is 190° Fah. When mixed with water, it becomes turbid and milky from the separation of the turpentine, which soon floats to the surface and forms an oily layer, the bulk of which is about half that of the original liquid. From this it would appear that it consists of about equal parts of strong alcohol and turpentine, the mixture being doubtless effected by distilling the two liquids together; for if alcohol and turpentine are merely shaken up together, they will not unite in this proportion: indeed, 100 parts of spirits of wine, of specific gravity 840, will only take up 13½ of turpentine; and alcohol of much less density (830) will not take up more than 20 per cent. of it.

When the French liquid is burnt in an ordinary open lamp, at the rate of 138 grains per hour, it gives a light which is about two-thirds as great as that of a standard sperm candle.

The great objection to the use of this liquid is its liability to explode when its vapour becomes mixed with atmospheric air. In consequence of this property, the greatest caution is necessary in manipulating with the fluid; for should an explosion take place, the most dangerous results might follow. We are not likely to employ the mixture in this country, on account of the high price of spirits of wine; but in France and Germany, where alcohol is comparatively cheap, the fluid is often used as an illuminating agent at railway stations in country towns.

(*b*.) *Coal-naphtha.*—When coal is distilled for the manufacture of gas, a tar is obtained which is the source of common naphtha. The tar itself is a very complex material, for it contains a number of oily acids, alkalies, and neutral bodies. As it comes from the gas-works it is a thick, dark liquid, of a most offensive odour. To extract from it its various constituents, it is put into large iron retorts or stills, and submitted to distillation; that which comes over first is of an aqueous nature, and smells strongly of ammonia; then follows a brownish oil, which floats on the preceding. After a time, a denser or heavier oil begins to makes its appearance; and when this happens the receiver is changed, and the first product is set aside for the manufacture of light oil or crude naphtha. The coal-tar generally yields from four to five per cent. of this fluid. As the distillation of the tar proceeds, a heavy oil, which falls to the bottom of water, and is hence termed dead oil, comes over. This is used, under the name of creosote, for the preservation of timber. After this a yellowish semi-crystalline fat, called naphthaline, makes its appearance; and, finally, a more solid material, named paranaphthaline, distils over. That which remains in the retort is pitch.

The crude coal-naphtha is rectified either by distilling it a second time, or by driving steam through it and collecting the condensed products. In this way it is separated from another portion of heavy oil which remains in the still.

The light naphtha thus obtained is sent into commerce, and sold for about 2*s*. 4*d*. per gallon, for combustion in the common vapour-lamps which are so frequently to be seen in the streets of London, lighting up the stalls of the poor tradesmen. In this condition it is an amber-coloured liquid, of a powerful gas-like odour and spirituous appearance. It has a density of from 860 to 900—usually it is about 887. It floats on water, like turpentine, and becomes darker coloured by exposure to the air. It mixes very freely with wood-spirit or with spirits of wine; and may thus be burnt like the last-named liquid, in an ordinary lamp.

The light naphtha is further purified for commerce by agitating it with a little oil of vitriol, then washing with water, and redistilling. In this condition it is sold as rectified naphtha. It fetches about 4*s*. per gallon, and is used for combustion in the naphtha spirit-lamps which have a flat wick and oval glass.

Mr. Mansfield has shown that light coal-naphtha contains a number of volatile oils, which may be separated from it by fractional distillation. One of these—namely, benzole—is of great importance. It is procured by boiling the naphtha in a retort to which there is adapted a worm which coils through a vessel of boiling water; the worm is so constructed that all the vapour which condenses in it shall run back again into the still, while the uncondensed vapour (that of benzole) passes on into another receiver, where it is cooled and collected. The benzole thus obtained is rectified a second time in a similar apparatus, the temperature of the worm being kept at about 176° Fah. In this way a large proportion of volatile oil is obtained, which is further purified by agitating it with one-fourth its bulk of strong sulphuric acid, or, better still, with about one-tenth of strong nitric acid; and then, after separating the nitric acid, it is agitated with oil of vitriol as before. The naphtha is now to be decanted and distilled a third time. If it be repuired to have the benzole perfectly pure, it is submitted to a cold of 4° Fah. This is produced by mixing salt and snow together. The benzole freezes and leaves its impurities in a fluid condition, from which it may be separated by means of a filter.

The use of sulphuric acid in this process is to remove all the basic substances, and to oxydize the brown colouring matter of the naphtha; the nitric acid assists the oxydation, and at the same time forms a small quantity of nitro-benzole, which gives a fragrant, almond-like odour to the product.

Benzole is a limpid, colourless liquid, of a rather ethereal odour; its density is 850—consequently it floats on water. It boils at a temperature of 177° Fah., and gives off a vapour which is very inflammable, burning with a sooty flame. It solidifies at the freezing-point of water, and then looks like camphor. So volatile and combustible is the liquid, that when a current of hydrogen gas is passed through the fluid, or through a sponge moistened with it, the gas will burn with an intensely white light. Atmospheric air charged with the vapour also burns with a smoky flame and a bright light: the flame is sometimes of a violet-blue colour when the apertures of the jet are very small.

Benzole mixes freely with alcohol or with wood-spirit, and the compound so formed burns in common lamps with a very powerful light. It is necessary that the mixture should bo made with proper proportions, or else the light of the flame is not good; for if there be too much spirit the light is blue, and if too little it is smoky. The mixture which is found to give the best results, is about one part benzole and two of spirit, of specific gravity 840. This mixture, when burning at the rate of 160 grains an hour, gives a light of from one and a half to two sperm candles.

The extreme volatility of benzole gives to coal-naphtha the property of naphthalizing air or bad gas; for if a little of the liquid be placed in the gas-meter, or in a chamber containing some pieces of sponge through which the gas passes, it will acquire increased illuminating powers. Mr. Lowe, of the Chartered Gas Company of London, has taken out a patent for this mode of naphthalizing gas. Beale's lamp is also a contrivance for naphthalizing atmospheric air. It consists of a cup of naphtha through which a stream of air is made to pass; and to facilitate the volatilization of the naphtha, a hot cap is placed over the cup, so as to communicate its heat to the air and liquid. The other constituents of coal-naphtha are not so volatile as benzole, and hence they are not fit for the purpose of naphthalizing. Mansfield states that the oil which distils over from the crude naphtha at a temperature of 230°, will take fire at its surface, but it yields so little vapour to cold air that the latter, when passed through it, burns with but a feeble blue flame; and the oil which distils at a temperature of 300° is still less inflammable, for it will not take fire at the surface, or furnish any combustible vapour to atmospheric air. In these respects it resembles turpentine, which requires a heat of 311° Fah. to boil it.

A fluid like coal-naphtha is also obtained from the distillation of certain oily matters, or petroleums, which exude from the earth. In many places in the neighbourhood of the Caspian Sea, in Ava, at the Tegernsee in Bavaria, at Amiano in Italy, at Neufchatel, at Saint Zibio in the Grand Duchy of Modena, at Clermont and Gabian in France, at Val di Noto in Sicily, at Rangoon, Barbadoes, Trinidad, Lake Geneka in New York, and many other places, an oily matter called rock-oil oozes out of the ground, and is collected in pits dug in the earth to receive it. When distilled, it furnishes a volatile oil called naphtha, of which Persian naphtha may be taken as a good example. It is colourless, limpid, very combustible, and burns with a sooty flame. In some places it is used for illuminating purposes.

(*e*.) *The Oil of Fermented Liquor, Oil of Grain, or Fusel-oil.*—In the process of fermentation, all saccharine fluids produce a volatile oil, which can be separated from the spirit by distillation. Pellitan, in 1825, first noticed this fact; and as he obtained the oil from spirit of potatoes, he called it potato-spirit oil. It was subsequently examined by Dumas (1834); and in 1839 it was investigated by Cahours. More recently Buchner obtained it from corn-spirit. For a long time it was obtained as a waste product by Mr. Bowerbank, a rectifier of London, who used it in his manufactory as an illuminating agent. The oil is procured at the end of the process for rectifying spirit. In its raw and impure condition it is usually called *feints*. It has the odour of bad whisky, and contains alcohol, and various fatty acids. By washing with water, then distilling with carbonate of potash, and, finally, with chloride of calcium, it is obtained in a tolerably pure condition. Five hundred gallons of corn-spirit yield about one gallon of oil. In its pure state, the oil has a peculiar ethereal odour, which, when inhaled, is rather unpleasant and irritating to the throat. Its specific gravity varies from 823 to 840; it boils at 268°, and emits a combustible vapour. The oil is not soluble in water, but it mixes with alcohol and wood-spirit in all proportions. It burns in an ordinary open lamp, with a clear and smokeless flame—the light of which is tolerably intense. A lamp that consumed the oil at the rate of 278 grains per hour, gave a light that was about half as good again as that of a standard sperm-candle. At present the oil is in demand for the manufacture of artificial essences, and consequently it is too expensive for combustion in lamps.

LAMPS.

History and General Principles of the Subject.—It has been already stated that the employment of lamps can be dated back to a very early period; indeed, it is generally thought that they were invented by the Egyptians, who not only used them for common illuminating purposes, but also placed them in the tombs of the dead as emblems of mortality. The ancient Greeks were likewise accustomed to the use of lamps, which we have every reason to believe were fed with a vegetable oil. Herodotus alludes to this fact; and it is further evidenced in many devices that we find sculptured in some of the most ancient Greek vases; but it was centuries after that before the Romans began to employ lamps, and then they were only used in the houses of the rich, or upon occasions of special festivity. That most of the classical nations have been accustomed to place lamps in the sepulchres of the dead is an instructive fact; for, although various motives have been assigned for the custom, there can be no doubt that it was intimately connected with their belief in the existence of a soul, and that it was meant to typify the departure of the spirit or vital fire from its frail tenement of clay. This is clearly set forth in many of the beautiful devices which adorn the funereal lamps of the early Greeks, where the immortality of the soul and its departure from the body is represented by the escape of a butterfly from an apparently dead chrysalis. The testimony of Pliny, St. Augustine, and others, has induced a belief that in many cases the sepulchral lamps were constructed so as to burn for ever; and some remarkable instances have been cited in which the lamps were said to have been found burning centuries after the tomb had been closed up; but none of these are sufficiently well authenticated, notwithstanding that Liceto and other authors have taken great pains to establish their truthfulness.

It is very probable that the earliest lamps were not made of any set form, but that the fat or oil was placed in any convenient vessel, and fired by means of a bundle of rushes or dried moss. As civilization advanced, and the necessity for artificial light increased, attention would naturally be directed to the form best suited to the wants of the people; and it is very likely that at first the lamp was nothing more than a circular vessel or saucer containing the combustible material. Lamps of this description are still employed on the Continent for purposes of general illumination. It is thought by some persons that the lamps of the virgins alluded to in the Gospel of St. Matthew (chap. xxv.) were merely rods of porcelain or iron covered with cloth, and steeped in oil or fat, and that the same kind of lamp or torch was used by the soldiers of Gideon; but we have no positive testimony in support of such an opinion, although there is plenty of evidence to show that lamps trimmed with oil were in use long before that time.

The next improvement in the form and construction of the lamp is to be seen in the ancient lamps of Herculaneum and Pompeii. Examples of these are to be found at the Louvre, the British Museum, the Vatican, and, indeed, in almost every considerable museum in Europe; but the finest specimens belong to the King of Naples, who has a collection of such things at Portici; in fact, in the sixth hall of that museum there is a large collection of lamps taken from the buried cities of Pompeii and Herculaneum. Besides which, Liceto, Bartoli, and Passeri have published descriptions and drawings of many hundreds of such lamps that were in the museums of Italy during the sixteenth century. The common form of all of them is that of an elongated vessel, like a boat, having the wick at one end (Figs. 6, 7, and 8); at other times it was a simple disc, with a hole for the wick on one or both sides, and an aperture in the centre for supplying the oil (Fig. 9). Lamps of the former description are still used by the poor of the Orkney and Shetland Isles.

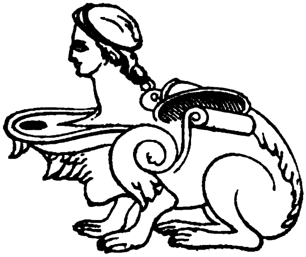

Fig. 6.

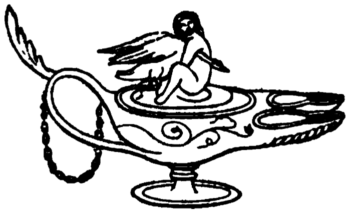

Fig. 7.

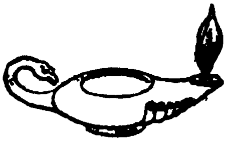

Fig. 8.

The material of which the Greek and Roman lamps were composed was chiefly *terra-cotta*, though some of the better sort were made of bronze, and even of silver and gold. A few ancient lamps of iron have also been discovered, but they are comparatively rare, perhaps because of the perishable nature of the metal. In the museum at Portici there are several iron lamps, together with one of glass, all of which were taken from the ruins of Herculaneum.

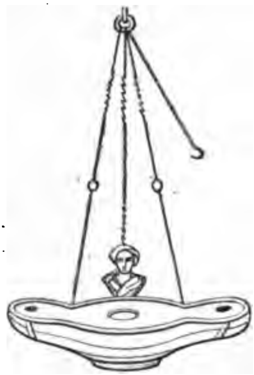

Fig. 9.

Much ingenuity was exhibited by the Greeks and Romans in the construction and ornamentation of the supports (the λυχνουχοι, *lampadaria* or *candelabra*) which held the lamps. At first these were composed of cane, and the Greeks in all their designs never lost sight of this fact; consequently we find a variety of vegetable forms blended with the stiff reed, giving it lightness and elegance: the twining ivy and the graceful acanthus were frequently associated in this manner. With the Romans, however, the usual support was a tripod resting on lions' feet.

At a very early period it must have been observed, that when an attempt was made to enlarge the wick beyond a certain point, the flame became dull and smoky. To remedy this, it was customary to split the wick up with a number of small flames, each of which would allow the atmosphere to play freely around it, and thus to keep up a tolerably good combustion. There is no doubt that this device was well known to the ancients (Fig. 8), though it is generally considered that Dr. Franklin was the first to show that the same quantity of cotton divided into two wicks gives a better light than when it is used as one; but the difficulty which presents itself in the employment of such a contrivance is that of keeping the wicks equally well-trimmed. To obviate this, the flat wick was invented; and thus a thin sheet of flame was produced, which allowed of much more perfect combustion. Nevertheless, with all these improvements, the light of the lamp could not be increased beyond a certain point without its becoming dull and the wick sooty; and consequently for many years the lamp was rarely used in the apartments of the rich, for fear of its doing harm to the walls and furniture by its great tendency to smoke.

In 1780, however, as we have already said, a great change was effected in the art of illumination by the discovery of M. Argand of Geneva, who found that whenever a due supply of atmospheric air was furnished to the inside as well as the outside of a flame, the combustion of the oil might be kept up to any amount without danger from smoke or bad smell. The plan which he adopted for accomplishing this was very simple. He made the wick hollow, and placed a glass around it so as to secure a strong current of atmospheric air to both sides of the flame. We shall have occasion to describe the details of his contrivance when we come to the subject of the various Argand lamps at present in use. All subsequent improvements on this invention of M. Argand have been with the view of adjusting the wick, of regulating the supply of oil, of doing away with the shadow cast by the reservoir, and of directing the current of atmospheric air into the body of the flame. The first object was accomplished by means of a rack and pinion, or by a point working in the thread of a screw; the second by various forms of fountains, syphons, and, in the Carcel lamp, by means of a piston which is worked by machinery. The wick has also been modified in its construction so as to suit the condition of the oil; it is made of fine web when the oil is very fluid, and of coarse web when it is thick. The third object has been accomplished by giving the reservoir an annular form—this was Count Rumford's invention—or by placing it above the level of the flame, as in Parker's lamps; and the fourth, by contracting the glass immediately around the wick, or by putting a metallic disc into the centre of the flame, as in the Vesta lamp; or by dropping a brass nipple over it, as is the case with the solar lamp. All these contrivances increase the supply of air; and, by breaking its course, they cause it to impinge upon the body of the flame.

For the combustion of volatile oils and naphtha, lamps of very different construction are required; especially in those cases where the oil or spirit is to be consumed in a gaseous form without the aid of a wick. We shall describe these lamps, which are of comparatively modern invention, when we speak of Beale's, Holladay's and Ludërsdorf's lamps.

With all lamps, however, the great principle that is to be kept in view is, so to adjust the supply of atmospheric air to the combustible, that on the one hand the flame shall not evolve smoke, and on the other it shall not be cooled or over-burnt; for, in the one case there is too little atmospheric air, and in the other there is too much.

Management of Lamps.—Lamps will not burn in a satisfactory manner if they are not kept clean and well trimmed; for, in the first place, nearly all the oils which are made use of at the present time are, more or less, drying in their nature, and consequently they are apt to become thick in the lamp, and to clog its several apertures. Whenever this occurs, the lamp ceases to burn; and there is no help for it but a good cleaning. This is accomplished by draining out all the oil as completely as possible, then charging it with a strong solution of soda or pearlash, which combines with the oil and forms soap. The solution ought to remain in the lamp for twenty-four hours, and it should be frequently agitated; but care should be taken not to spill any of the liquor over the paint or lacquering of the lamp, for fear of dissolving it off. After it has stood in this way for the necessary time, the soapy liquid may be run out, then washed clean away with warm water; and, finally, the lamp is to be well dried. Some of the very common oils are so liable to resinify, that it is necessary to change the wick every day: this is the case with the oils that are used in Parker's hot-oil lamp, and consequently it is trimmed with a very short wick. In the second place, the wick should be properly attended to: if a solid wick is used it should not be twisted too tight, for fear of stopping the capillarity for the oil; nor should it be too loose, for then it is apt to accumulate soot. If the Argand, or hollow wick, is employed, it should be selected with due regard to the quality of the oil; for a thick or fatty oil requires a coarse texture, and a very fluid oil a fine one. The top, or carbonized portion of the wick, should always be removed immediately before the lamp is lighted; for this is so changed by the action of heat, that the oil will not rise in it; indeed, the common oils are so disposed to char and clog this portion of the wick, that it sometimes requires removal several times in the course of an evening. The wick should be cut perfectly level, or the flame will be irregular, and will smoke. Lastly, in cold weather it is advisable to warm the oil before the lamp is lighted.

The relative Illuminating Power and Economy of different Lamps.—This is a subject which has not been well investigated; for the difficulties connected with it are extremely great. At the Exhibition of 1851, there were forty-nine lamps sent for examination; but the jurors declared that it was a matter of impossibility to test their value. M. Peclet is nearly the only person who has devoted attention to this subject; and the following table is constructed in great part from his investigations:—

Lamps.	Consumption per hour.	Luminosity in sperm candles of 120 grains.	Relative power for equal weight.
1. Vesta lamp without button (camphine) . .	140 grains	2·6	185
2. Ditto ditto ditto (with coal-naphtha)	136 ,,	2·0	147
3. Common Argand	350 ,,	4·0	114
4. Carcel lamp	630 ,,	7·0	111
5. Sinumbra, with lateral fountain . . .	270 ,,	2·9	109
6. Thilorier's or Parker's lamp	767 ,,	7·6	99
7. Sinumbra, with fountain above . . .	645 ,,	6·3	98
8. Common sinumbra	645 ,,	6·0	91
9. Gerard's hydrostatic	521 ,,	4·5	86
10. Common open lamp	103 ,,	0·8	77
11. Eclairage au gaz	343 ,,	2·1	61
12. Fountain lamp, with flat wick . . .	165 ,,	0·9	54
13. Dome Argand	400 ,,	2·1	52

Varieties of Lamps.—These are so exceedingly numerous that it is not possible, in a work like the present, to give anything more than a very general account of the most important. Indeed, there are but few really distinct principles involved in the construction of lamps, notwithstanding that there are so many modifications in their form and arrangement; we shall have no difficulty, therefore, in understanding the construction of any lamp, after we have become acquainted with the following varieties. It is proper to add, that we are indebted to the "Encyclopædia of Domestic Economy" for many of the illustrations which we are about to offer, and that the reader will therein find a very good description of the lamps now in use.

1. **Common Oil Lamp, without any Glass.**—Of these there are several:—

(*a.*) *The Common Lamp of the Shetland and Orkney Islands* (Fig. 10).—This is contrived for the combustion of common fish-oil, and the wick that is used is nothing more than a bundle of dried rushes. A lamp of similar construction is used by the Esquimaux, who employ a wick of dry moss.

(*b.*) *The Common Street Lamp* (Fig. 11) was once to be seen at the stalls of poor tradesmen; though it is now almost entirely displaced by the common naphtha lamp.

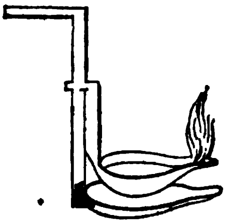

Fig. 10.

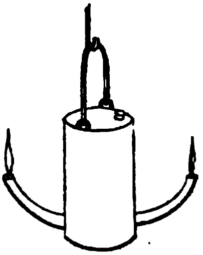

Fig. 11.

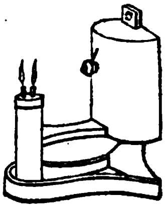

Fig. 12.

It is a tin vessel, with one or two spouts emerging from the sides close to the bottom. These are packed pretty tightly with cotton wick; and being constructed on the principle of the bird-fountain, the oil flows very freely to the top of the wick, but does not run over.

(*c.*) *The Fountain Lamp* (Fig. 12) is constructed on nearly the same plan as the last; and as the reservoir for the oil is above the level of the wicks, the flame burns with the same brilliancy as long as any oil remains.

(*d.*) *The Common Domestic Lamp* (Figs. 13 and 14) is made to fit a candlestick. It is a very economical lamp; though from the circumstance that the flame is situated at a considerable distance above the level of the oil, there is some difficulty in getting the lamp to burn when the oil is at all thick, or when the wick is clogged by age.

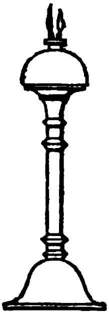
Fig. 13.

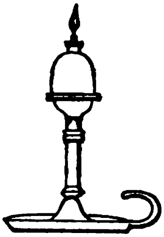
Fig. 14.

2. **Common Lamp with a glass or shade.**—Most of the preceding may be improved by surrounding the flame with a glass, to keep off the currents of atmospheric air, which cause the light to flicker. The principal of these are represented in Figs. 15, 16, and 17; and to the same category belong the floating night-lights (Figs. 18 and 19), which are either pieces of waxed wick supported on strips of tin, and kept floating by means of cork, or else little caps of thin brass pierced with a hollow glass tube, in which the oil rises and burns. The safety-lamp of the miner (Fig. 4) is nothing more than a common lamp, the flame of which is surrounded by a shield of wire-gauze; and in the lamp of Upton and Roberts there is an additional shield of glass.

3. **Common Lamp with Oxydator.**—It is found that when a current of atmospheric air is made to impinge on the flame of a common lamp, the light is much more steady and brilliant. Various contrivances have, therefore, been adopted for the purpose of effecting this; as, for example, the bending in or contracting of the glass immediately around the flame (Fig. 20); or the fixing of a metal or mica disc around it (Fig. 21); or, better still, the dropping of a perforated nipple over the flame, as is seen in Fig. 22. The last constitutes the principle of the solar lamp, to which we shall have occasion to refer by and by. It was, we believe, first contrived by Mr. Roberts, the miner, and was applied to his form of the improved Davy.

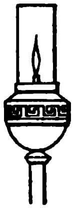
Fig. 15.

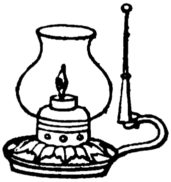
Fig. 16.

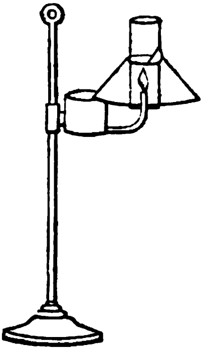
Fig. 17.

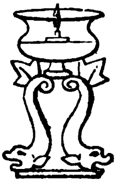
Fig. 18.

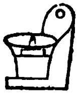
Fig. 19.

4. **The Argand Lamp.**—This differs from all others, in the circumstance that the wick as well as the flame is hollow; and it is so contrived that a current of atmospheric air plays on both sides of the flame, and so increases its brilliancy. There are several modifications of this lamp, of which the following are the most important:—

(*a.*) *Common Argand Lamp* (Fig. 23), which consists of a vase *a* to hold the oil; a cistern *b* to supply the burner; and an arrangement *c* for adjusting the hollow wick, and allowing a supply of atmospheric air on both sides of the flame. The oil is put into the vase *a* by unscrewing it from *b*, and then running in the oil through the hole *d*, or else through the aperture in the bottom, which is usually closed by the plug *f*. The hole *d* is then closed by drawing up the handle *g*, which communicates with a sliding tube *h*, and the vase is returned to its place on *b*. When the lamp is lighted, the handle *g* is to be depressed: this causes the oil to escape through the hole *d* into the cistern *b*; and from this it runs by the side tube *i i* into the conical chamber *o*, which contains the wick *n*. This chamber consists of two tubes, *k k*, *l l*, one within the other, and joined at *m m*, so as to make a closed receptacle for the oil. In this receptacle the wick *n* plays freely up and down; and it is kept constantly immersed in oil, as high as the aperture *d*, in the cistern *b*. *p* is a cup placed at the bottom of the chamber to receive any oil that may run over from the wick. Atmospheric air rises freely through *c* into the centre of the flame, and it also blows upon the exterior of it: the cause of the current of air is the glass chimney which rests on the top of the burner.

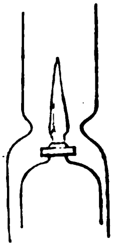
Fig. 20.

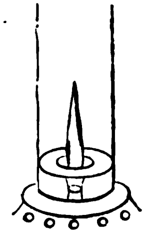
Fig. 21.

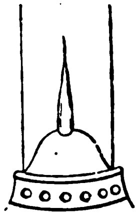
Fig. 22.

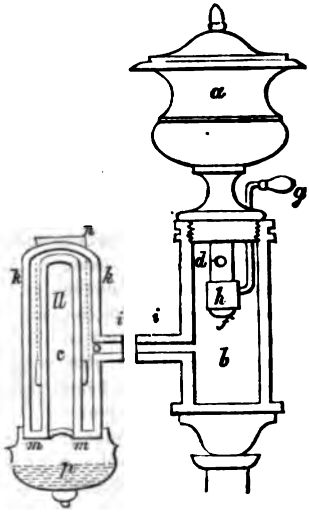

Fig. 23.

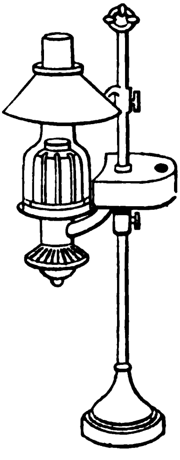
Fig. 24.

Many forms have been given to this lamp of M. Argand, according to the purpose which it is intended to serve: thus, there is the reading or Cambridge lamp (Fig. 24), the well-known table lamp (Fig. 25), and the suspended lamp.

(*b.*) *The Rumford or Annular Table Lamp* is an improvement on the last. It was contrived by Count Rumford, for the purpose of avoiding the deep shadows which are produced by the reservoirs of the preceding; and it became so great a favourite that even to this day it is very generally used. The oil is contained in a hollow ring which is placed a little below the level of the flame; and the cistern is fed by means of two tubes, which also serve as supports. In order to diffuse the light still more, the burner is surrounded by a ground-glass shade, which almost entirely conceals the ring (Fig. 26).

(*c.*) *Parker's Sinumbra Lamp* was patented in 1820. It was called the shadowless lamp, because it did away with the slight shadow which is always perceptible in the last. The improvement is threefold:—first, the annular reservoir is bevelled off from above, so as to present a very thin edge on the outside; secondly, the glass is shaped in such a manner as to diffuse the light over the edge of the ring, and under it; and, thirdly, a conical reflector is placed around the inner glass a little above the flame. All these arrangements are represented in Fig. 27, which shows the lamp in section.

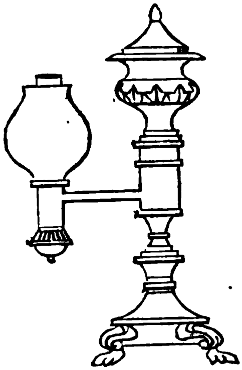
Fig. 25.

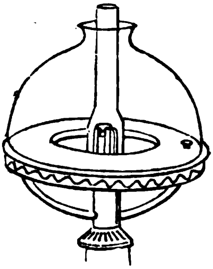
Fig. 26.

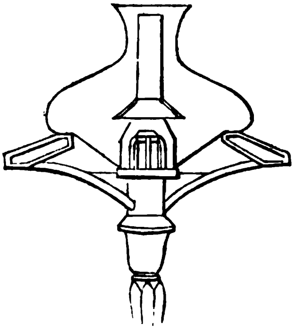
Fig. 27.

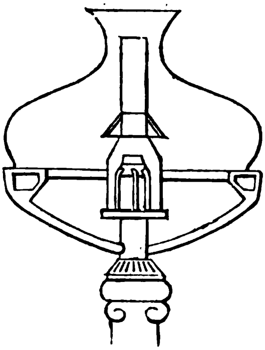
Fig. 28.

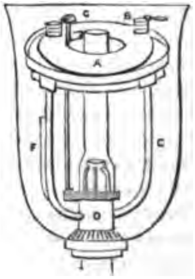

Fig. 29.

(*d.*) *Quarrel's Sinumbra Lamp* (Fig 28) is another contrivance for effecting the same object as Parker's; but the bevelling of the reservoir is on the under surface of the ring, instead of the upper; and the ground-glass shade is made sufficiently large to reach to the very outer edge of the ring.

(*e.*) *The Iris Lamp* is one of the most recent improvements of the Rumford and Argand: it differs very little from the preceding, except that the outer edge of the annular chamber is reduced to a mere bead; and the ground-glass shade is not only brought to the very front of the ring, but its body is formed in such a way as to bulge over it. By these contrivances the shadow of the reservoir is reduced to a minimum.

(*f.*) *Quarrel's Albion Lamp.*—This marks the next attempt to improve the Argand, by carrying the reservoir for the oil over the flame, and, therefore, out of the way of the shadow, instead of having it, as in Rumford's contrivance, around it and a little below it. The construction of this lamp is represented in Fig. 29: A is the reservoir for holding the oil, which is introduced through the two valve-cocks B; C is the tube that conducts it to the cistern D; and F is a syphon-valve for admitting atmospheric air to the reservoir, so as to supply the place of the consumed oil. G is a pinion for regulating the height of the wick. The whole is enclosed in a tulip-shaped glass; and, with the exception of the side-tubes, there is nothing to produce a shadow.

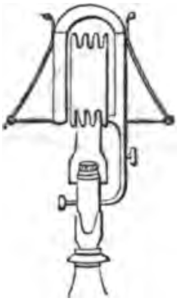

Fig. 30.

(*g.*) *Parker's Hot-oil Lamp* is constructed somewhat like the preceding, though a contrivance is adopted for making the oil hot before it reaches the wick; by which means it becomes more fluid, and burns with greater facility. Fig. 30 shows the plan of this lamp. The reservoir is above the flame, and the top of the glass is fitted into an iron chimney, which radiates heat very freely to the reservoir. The oil passes down through a lateral tube to the cistern, and there is a stop in the tube to cut off the supply of oil when necessary. The wicks are very short; and instead of their being adjusted by the rack and pinion, a movement is given to the glass, which, by its position, regulates the intensity of the flame. A painted shade is put over the whole, in order that the reservoir may be hidden. The advantage of this lamp is, that it will consume the very commonest oil without producing an unpleasant smell. One caution, however, is necessary in the management of it—namely, that the reservoir be filled quite up with oil before the lamp is lighted. If this be not attended to, the air contained in the chamber will expand by the action of the heat, and the oil will be forced out over the wick and will run about.

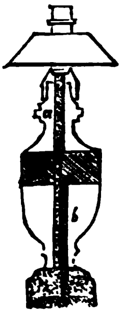

Fig. 31.

(*h.*) *Keir's Fountain Lamp.*—In all the preceding contrivances, the supply of oil to the flame is chiefly effected by the capillarity of the wick. In some cases it is assisted by the gravitation of the oil from a reservoir situated above the level of the burner. But it has always been thought desirable to have the reservoir in the stem or body of the lamp, so that the unsightly appearance of the chamber might be avoided, and the shadow which it invariably casts to a greater or less extent upon surrounding objects, entirely prevented. This, however, can only be accomplished by means of some power whereby the oil shall be pressed up from the well in which it is contained, to the level of the flame. "To effect this, two methods have been resorted to: one is on a hydrostatic principle, in the manner of Hiero's fountain, where the oil is placed in the body of the stem, and is raised to the wick as it is wanted by the pressure of a column of some fluid: in the other method, the oil is forced by clock-work mechanism, as in the lamp of Carcel of Paris. The first successful attempt of this kind in England, was in the lamp invented by Mr. Keir, about forty years ago, upon a hydrostatical principle; and although it is not used at present, being superseded by contrivances of a similar kind by other manufacturers, yet it will serve to illustrate the general nature of these lamps, of which several varieties have been brought partially into use."—(Webster and Parker, p. 159). Fig. 31 represents Keir's lamp, the vase and pedestal of which are hollow. *a* is a tube into which a certain quantity of salt-and-water, having three times the specific gravity of oil, is put. Upon this is poured the oil until the tube is full. The brine, or solution of salt-and-water, runs down into the pedestal of the lamp; and when the oil is poured upon it, the latter by its weight forces up the former through a second tube *b*, into a chamber *c*, in the upper part of the body of the lamp, and the oil takes the place of the brine in the pedestal. It will be noticed that the tube *a* reaches only to the top of the chamber in the pedestal, while the tube *b* passes down to the bottom of it. The brine is represented by diagonal lines, and the oil by dots. Now, in consequence of the great weight of the brine, as compared with that of the oil, the latter is forced up to the burner as fast as it is consumed; and thus, by a sort of natural spring, the flow of oil to the wick is constantly maintained. After a supply of salt-and-water has once been introduced into the lamp, there is no necessity for a further addition of it.

Similar lamps have been constructed on the same principle by King, Barber, and others; but they are all difficult to manage, and hence they are not much in vogue, although they generally have a very light and elegant appearance.

(*i.*) *Parker's Fountain Lamp* (Fig. 32) is a very complicated apparatus, which, like the fountain of Hiero, owes its action to compressed air. Externally it presents the appearance of a column surmounted by the lamp; but within this column there is another cylinder which contains the oil. This cylinder must be removed before the lamp can be charged. It is divided crosswise into three compartments, *a*, *b*, *c*, which have no direct communication with each other. Through the centre of the whole there passes a tube *f*, which is open at top, and at bottom it communicates by a sort of valve with the compartment *c*; it also communicates with the compartment *a*, by means of a hole which is seen near the top of the tube. The three compartments or chambers are therefore in indirect communication with each other; thus *a* communicates through the hole just mentioned with the tube *f*, this communicates by its bottom valve with compartment *c*, and this, by means of a tube and valve *g*, with the middle compartment *b*; and *b* communicates by means of an ascending tube with the burner *i*, in which the wick is placed: so that if oil be poured into the upper opening of the tube *f*, it will fill the compartment *c*; and then on turning the apparatus upside-down, the oil will flow through *g* into the middle compartment *b*. On restoring the cylinder to its proper position, the oil cannot return to *c*, because of the peculiar form of the contrivance *g*—consequently it remains in the middle chamber; and now, on refilling *c* through the tube *f*, the air in the lowest chamber is compressed, and it forces the oil in *b* up through the lateral tube to the burner *i*. The chamber *a* is filled at the same time as *f*, and its contents flow as fast as they are wanted through the hole in the tube *f*, and thus keep up a supply to the pressure-column. Every time the lamp is charged it is inverted, in order that the oil in *c* may flow into *b*; and then it is returned to its original position, and recharged with oil. This lamp was reported on by the French Academy of Science, and it was formerly much used in India; though now it is superseded by the Iris lamp.

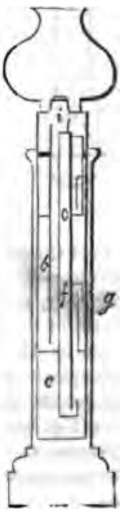

Fig. 32.

(*k.*) *The Carcel Lamp* is very generally used at the present time. It presents much of the appearance of the last described; but instead of the flow of oil being effected by means of atmospheric elasticity, it is accomplished by the aid of machinery moved by clock-work. In this way the oil is raised, or rather pumped up, to the wick, so as to keep up a constant supply by continually overflowing it. The oil drips back into the cistern below; whence it is drawn up again and again, until it is all consumed.

(*l.*) *The Solar Lamp.*—This is Roberts's great improvement on the Argand, although it was patented by Mr. Bynner. It is a contrivance for increasing the supply of atmospheric air to the flame, and so enabling it to consume a larger proportion of oil, and thus to give out a greater body of light; besides which, it effects a more complete combustion of the oil, and, therefore, produces a more intense light. In all the common forms of Argand, the air passes straight up through the burner, and only slightly impinges on the two sides of the flame; but in this contrivance the current of air is broken, and made to blow in upon the flame. The apparatus which effects this is a small cone or nipple, that is dropped down over the flame (Fig. 33).

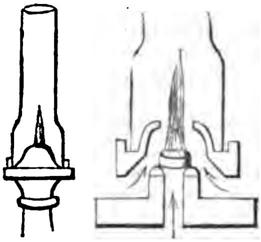

Fig. 33.

A still greater improvement on this principle is that of Quarrel, in which he causes a second current of air to enter under the glass, and thus to assist the other in blowing on the flame (Fig. 34); and by introducing a button into the centre of the flame (as was also originally proposed by Mr. Roberts), this inner current of atmospheric air is likewise deflected, and thus we get the greatest possible amount of oxydation (Fig. 35). By the adoption of such contrivances as these, almost any kind of oil, even the commonest fish-oil, may be burnt without smell.

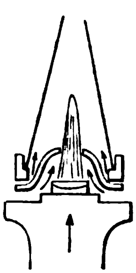

Fig. 34.

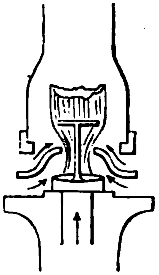

Fig. 35.

(*m.*) *The Bude Light* of Mr. Goldsworthy Gurney is only an extension of the preceding principle. Roberts increased the supply of atmospheric oxygen, by means of the nipple, which others patented and applied to the solar lamp. Mr. Gurney, however, uses a jet of pure oxygen, or of an atmosphere rich in oxygen, which he throws into the centre of the flame by mechanical power; and by this means he increases combustion and light to an enormous extent. This light requires complicated apparatus for its production, and hence it has never come into general use.

(*n.*) *The Argand with Concentric Wicks.*—Many years since Mr. Webster suggested that Argands might be made with two circular wicks, one within the other; and Sir Humphry Davy referred to the invention as one well adapted for obtaining heat for chemical purposes. A lamp on the same principle, with four concentric wicks, has since been constructed, by M. Fresnel, for light-houses; and, according to Dr. Brewster, it gives a light equal to forty common Argands; but the heat produced by the lamp is very intense.

5. **Lamps for Burning Solid Fats.**—The commonest form of these is the saucer and central-wick lamp, which may be seen so frequently in France during the nights of illumination; but a more agreeable form has been given to this kind of lamp by the Hon. G. Cochrane, who took out a patent for it a few years ago. His lamp is very much like an ordinary Argand, but it has a piece of metal over the flame which communicates with the chamber containing the fat, and thus keeps it warm and liquid (Fig. 36). The fats which are best suited for this lamp are cocoa-nut and palm; but tallow and kitchen-stuff may also be used.

6. **Camphine or Vesta Spirit Lamps.**—These are the names given to the lamps which are constructed to burn the highly rectified oil of turpentine—a liquid which Mr. English originally prepared and patented under the name of camphine. Mr. Young, of Queen Street, Cheapside, has devoted great attention to the manufacture of these lamps, which he calls *Vesta spirit lamps.* The reservoir for holding the camphine is made of glass, in order that the heat from the burner may not be communicated to it: in fact, every precaution is taken to guard against such a result; for the wick, instead of being supported on a long metal tube, which passes down into the body of the oil, as is the case with the common Argand lamps, is merely held at the top by a narrow ring, while the remainder of the wick floats freely in the spirit; besides which, the burner is insulated from the lamp by a collar of wood. The next point of importance in their construction is that which ensures an abundant supply of atmospheric air; for if this is not provided for, the turpentine burns with a remarkably sooty flame, and evolves a large quantity of blacks. This is effected by having a slit in the side of the wick so as to allow the atmosphere to pass freely into its interior; and the nipple, or cap, of the solar lamp is used to break the outer current of air and blow it into the flame; besides which, the chimney is very tall, and it is bulged in, or contracted, at the point where it reaches the flame. In the larger kinds of camphine lamps, the button of Mr. Roberts is also introduced into the interior of the flame, so as to break the inner current of atmospheric air (Fig. 37). And then, in addition to all this, a cylinder of perforated brass is put around the vent-holes of the burner, so as to prevent the ill effects of extreme draughts. The principles, therefore, which are kept in view in the construction of these are —1st, to prevent the heating of the liquid; 2nd, to ensure a large supply of atmospheric air; and 3rd, to guard against the influence of external draughts. One of the great advantages of the Vesta lamp, is the intensity and purity of the flame. Dr. Ure says that a lamp which consumes two ounces of camphine in an hour, gives the light of nearly twelve sperm or wax candles of three or four to the pound. Our own experiments show that the smaller lamp which has no button, consumes about 140 grains per hour, and gives the light of two and a half sperm candles, each burning at the rate of 120 grains per hour; while the larger lamp, which has the button, consumes about 540 grains of camphine per hour, and gives the light of seven sperm candles.

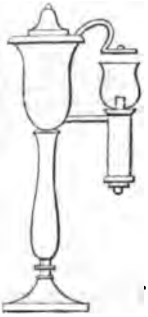
Fig. 36.

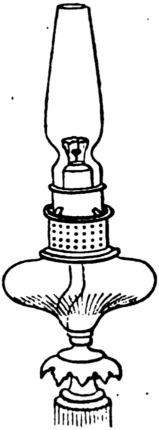
Fig. 37.

Among the disadvantages of the Vesta lamp are its liability to smoke, and its disagreeable smell. The former may arise from bad management, or from a resinification of the camphine—a circumstance that is sure to occur if the tin-can containing the liquid is not kept well corked, or if too much liquid is put into the lamp for an evening's consumption.

7. **Naphtha Lamps.**—Of these there are two kinds—viz., the Argand naphthas, which are constructed exactly like the preceding; and the flat-wicked lamp, which is represented in Fig. 38. In the latter, the air is directed upon the exterior of the flame

by means of two lateral pieces of tin, which incline inwards as they ascend to the wick; and the supply of air is regulated by an external opening or valve, which may be shut up to any extent. When naphtha is burnt in a small Vesta lamp, it is consumed at the rate of about 136 grains per hour, and it gives the light of two standard sperm candles; when burnt in the large one, its consumption is 436 grains per hour, and its light is equal to nine sperm candles. The disadvantages of these lamps are, the unpleasant smell of the naphtha, the liability to smoke, and the danger of explosion; for naphtha, being much more volatile than camphine, is likely to give off vapour, which with the air forms an explosive mixture. Great caution is therefore necessary in managing these lamps.

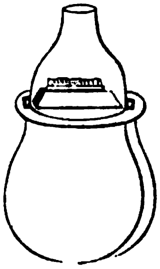

Fig. 38.

8. **Gas or Vapour Lamps.**—Several attempts have been made at various times to burn inflammable liquids without a wick. The earliest and simplest of these is

(*a*.) *The Common Floating Night-lamp*, which is nothing more than a small cup of metal pierced in the middle with a small glass tube. The oil rises by capillary attraction in the tube, and may be ignited.

(*b*.) Another form of *self-generating lamp* is represented in Fig. 39, where two tubes, *a a*, bring the oil down from the annular reservoir, and convey it into a cistern, whence it rises by the tube *b* into a cup which has a cylinder filled with it, pierced with a number of small holes that serve for jets. When the lamp is trimmed, alcohol is poured into the cup, and set fire to. This in the act of burning makes the cylinder so hot that the oil within it is converted into gas; and this escaping through the hole or jets, is fired and burns with a brilliant light. The heat produced by the combustion of the gas, keeps up the supply. A glass is placed around the burner to protect it from external currents, and to prevent the flame from smoking.

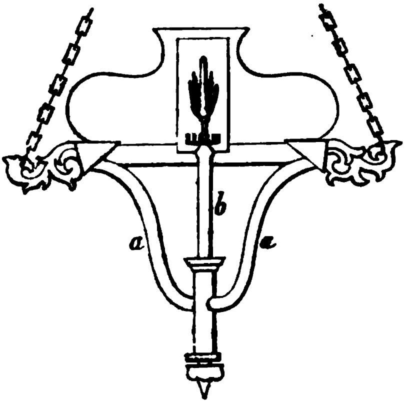

Fig. 39.

(*c*.) A mixture of camphine or highly rectified spirits of turpentine with alcohol, is burnt on the Continent in a lamp that was originally designed by Ludërsdorf, but which has been patented in France by Ribot under the name of "*Eclairage au Gaz liquide.*" The French lamp is represented in Fig. 40. It is an elegant-looking lamp, the body and stem of which are composed of cut glass. Fig. 41 exhibits the mechanism by which the spirit and turpentine are converted into vapour. *a* is the wick which floats in the liquid and conveys it up through the tube *b* into *c*, which is the vapour chamber; *d* is a cap of brass, which when heated effects the vaporization of the liquid, and causes the gas to escape through three little holes at its base; *f* is the collar for holding the glass; and *g* is a handle for turning the liquid off or on. When the lamp is to be lighted, it is filled up with mixed spirit; and the glass being removed, the handle *g* is to be turned from the left to the right. A ring of wire-gauze, saturated with the spirit, is then lighted and brought down over the cap *d* as low as *e*. This is to be kept burning until the metal cap and chamber are sufficiently heated to generate gas, which will escape through the holes and take fire. When this has occurred, the glass is to be replaced, and the burning jets will keep up the desired temperature. Instead of turpentine and alcohol, a mixture of equal parts of spirits of wine and coal-naphtha, or even coal-naphtha itself, may be used. The disadvantages of the lamp are its liability to go out with the least draught of air, and its danger of exploding.

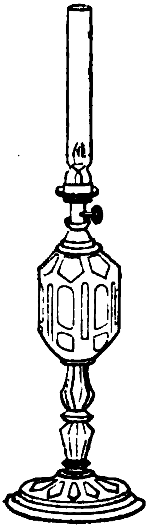
Fig. 40.

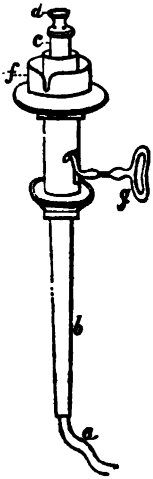

Fig. 41.

(*d.*) *The Common Naphtha Lamp* is now extensively employed by poor trades-people who have their stalls out of doors. The construction of this lamp will be understood from Fig. 42: *a* is the reservoir for the naphtha, from the bottom of which there passes a tube *b*, which supplies the fluid to the burner *c*. A stop-cock is inserted into the middle of the tube, in order that the supply of naphtha may be regulated, or even cut off altogether, when it is not wanted at the burner. Fig. 43 exhibits the construction of the latter: the naphtha enters by the tube *a*, and it flows out of a small hole which is in the lower arch of the burner, and trickles down into a small cup *b*; here it is lighted, and soon the combustion of the naphtha produces so much heat that it makes the whole body of the burner very hot. This causes the naphtha to assume the form of vapour or gas; and as it issues out of the small hole, it is forced up against the bottom of the disc *c*; and thence it comes spreading out in a star-like form all round the burner. This form is given to it by the little breaks of perpendicular wires which descend from the bottom of *c*; another small disc is placed below this to prevent the flame from bounding back upon the jet whence it issues from the tube; *d* is a small wire which is withdrawn when the interior of the burner wants cleaning.

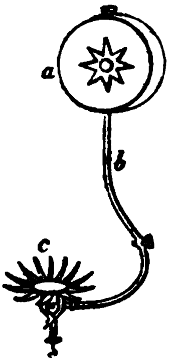

Fig. 42.

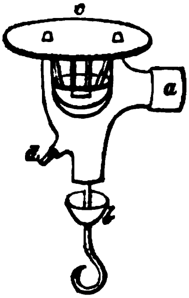

Fig. 43.

(*e.*) *Beale's Naphtha Lamp.*—This form of lamp was invented some years ago by Mr. Beale of London: it consists of a vessel *a* (Fig. 44) in which the naphtha is placed; thence it flows by a lateral tube into the cup-shaped cistern *b*, and it is prevented from overflowing by reason of its being constructed in the same way as a bird-fountain. A tube passes up through the bottom of the cistern, and reaches a little above the level of the liquid: this tube is placed in communication with a reservoir or gasometer containing air. Lastly, a brass cap *d*, having a hole in the top, is placed upon the cistern; the lamp is put into action by removing the cap and setting fire to the naphtha; air is then blown through the tube *c*, and the cap is gradually brought down into its place in the cistern, care being taken that it is sufficiently heated during its descent to keep up the volatilization of the naphtha. When this is properly managed, the air which passes through the tube *c* carries with it so much naphtha vapour as to become inflammable; and as it issues from the hole in the top of the cap, it burns with a brilliant jet of flame.

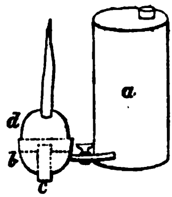

Fig. 44.

We have not thought it necessary to give a description of the different ornamental contrivances for setting up and supporting lamps, &c.—as, for example, candlesticks, candelabra, chandeliers, &c.; for this would entail a very elaborate account of the principles of ornamentation, which is not suited to the object of this work.

ON GAS.

General Remarks.—Long and long enough before gas was manufactured artificially, it was generated in the great laboratory of nature by the action of terrestrial heat on large accumulations of vegetable matter, as beds of coal. The products of this action made their way to the surface of the earth, and escaped in the form of gas and petroleum; both of which are highly inflammable. The fires thus generated commanded attention at a very early period, and altars dedicated to the gods were erected over them. At the time that the Persians, under the command of Mardonius, overran Greece, there were innumerable altars lighted up in this manner; and so much were they reverenced by the Greeks, that when the Persians were defeated at the battle of Platæa and driven from the country, the two victorious generals, Pausanias and Aristides, were directed by the Oracle of Delphi to build an altar to Jupiter, their deliverer, and not to offer any sacrifice upon it until they had extinguished all the fires throughout the country which had been polluted by the Persians, and had relighted them with the sacred fire from Delphi. In Plutarch's life of Alexander, we are told that when that monarch arrived at Ecbatana, "he was particularly struck with a gulf of fire, which streamed continually, as from an inexhaustible source. He admired also a stream of naphtha not far from the gulf, which flowed in such abundance that it formed a lake. The naphtha in many respects resembles bitumen, but it is much more inflammable; before any fire touches it, it catches light from a flame at some distance, and often kindles all the intermediate air. The barbarians, to show the king its force and the subtlety of its nature, scattered some drops of it in the street which led to his lodgings; and standing at one end, they applied their torches to some of the first drops, for it was night. The flame communicated itself swifter than thought, and the street was instantaneously all on fire."

For several thousand years the Chinese province of Se-tschuan has been celebrated for the quantity of inflammable gas that issues from the earth; and to this day it is said, that the gas which escapes from the ground in the neighbourhood of Pekin is collected by the inhabitants and used for lighting the streets and houses. The holy fires of Baku, near the Caspian Sea, have a similar origin; and jets of inflammable air are evolved at Pietra Mala, not far from the road between Florence and Bologna; at Maina, which is a few miles from Modena; at Lycia in Asia Minor; and at the Artesian wells of Lichweg in Schauenburg. In this country the gas is abundantly evolved from the fissures of coal mines, where it is known by the name of *fire-damp;* and it is also evolved from stagnant pools, when it is termed *marsh-gas.* At the village of Wigmore in Herefordshire, inflammable gas has on several occasions escaped from the earth in such large quantity, that it has been made the means of lighting the neighbourhood. The same has been the case at Charlemont in Staffordshire, and at Bedley near Glasgow. Not long since a considerable jet of gas was discharged from the Chat Moss, near to the Manchester and Liverpool Railway, and it was used by a neighbouring farmer for the purpose of working a small steam-engine. In the village of Fredonia, in the State of New York, the gas issues from the earth in such abundance, that the inhabitants collect it, and employ it for lighting the streets.

History of Gas Lighting.—It would naturally be supposed that facts like the preceding would, at a very early period, have commanded the attention of practical men of science, and that some effort would have been made to imitate the process which they saw going on in nature. Some, indeed, have thought that the ancient Greeks were really acquainted with a mode of generating gas, and that the chief priests took advantage of such knowledge in exciting the veneration of the people. The altar in the Temple of Ægina is described by Dr. Dodwell as having a round hole, thirteen inches in diameter, cut out of the top of it. This hole communicates with another which passes down through the solid stone to the depth of several feet, and there it opens into a cavity which is supposed to have contained fire that was always burning. He says that nothing more was necessary than to pour oil into the upper opening; and as it trickled down, it would be converted into gas, which would burst forth as flame, and appear to have a miraculous origin. But however possible, or even probable, the truth of this supposition may appear to be, it is certain that nothing of the kind was practised in Europe until the beginning of the seventeenth century, when Van Helmont, the physician and alchymist of Vilvorden, was led, in the course of his investigations, to expose a quantity of animal and vegetable matter to the action of heat in a closed vessel. By this means he obtained a vapour or spirit that burnt with a bright flame; but he little imagined that this *gaz fuliginosum,* as he termed the vapour, would one day become an agent of general illumination. Nor even at a much later period—namely, in the year 1726—when Dr. Hales informed the chemists of his time that by distilling a few grains of Newcastle coal he had obtained an equal number of cubic inches of inflammable air, could it be supposed that a similar experiment on a very gigantic scale would be daily performed in every city in Europe, and that millions upon millions of cubic feet of that subtle, inflammable material would be made to traverse, unseen, along the highways of the land, and be the means of lighting them up into perpetual day.

Again, we may take up the history of our subject from another important discovery. Some time before the death of the Honourable Robert Boyle (1691), a letter was written to him by the Rev. Dr. Clayton on the subject of distilling pit-coal. That letter was published many years afterwards—namely, in the year 1739—in the Transactions of the Royal Society; and the author states that from an examination of some inflammable vapours which were given off from a ditch near Wigan in Lancashire, vapours which had been collected and examined by Thomas Shirley in 1659, he was led to conclude that they came from the coal of the neighbourhood, which was acted on by terrestrial heat. Accordingly, he obtained a portion of the coal, and distilled it in a retort over an open fire. By this means he obtained a phlegm, which first passed over; then a black ore; and lastly a spirit, which he could nowise condense, for it forced the luting of his apparatus and broke his glasses. This spirit was coal-gas; and on discovering its inflammable nature, he was in the habit of collecting it in bladders and oiled silk-bags, and thus preserving it for the amusement of his friends.

As yet, however, he had not leart to burn it from a metallic jet, for he was accustomed to prick a hole in the bag, and then to set fire to the gas as it issued forth. For a period of more than fifty years these interesting facts were allowed to slumber, and no one entertained the idea of applying them to any useful purpose. At length, in the year 1792, just one hundred years after Boyle's death, an ingenious engineer and miner of Cornwall, whose name was Murdoch, conceived the notion that gas might be conveyed through pipes to a distance, and be thus employed as an illuminating agent. Acting upon this idea, it was not long before he had the satisfaction of seeing his house and offices at Redruth lighted up with Dr. Clayton's subtle spirit. He also collected the gas in bladders, and used it as a means of lighting himself along the road between the mines and his own house; for which piece of ingenuity he acquired the reputation of a wizard. Soon after this Mr. Murdoch was employed in the establishment of the celebrated engineers, Messrs. Bolton and Watt. There he erected apparatus for the manufacture of gas; and at the Peace of Amiens in 1802 he lighted up their factory for the first time with this agent. About a year afterwards gas was generally employed in all the workshops of the factory; and in 1804 he set up a similar apparatus in several of the large cotton-mills of Lancashire—one of the earliest of which was at the establishment of Messrs. Phillips and Lee at Manchester.

Ten years after this—namely, in 1813—the manufacture of gas had extended to London, and in that year Westminster Bridge was lighted with it. Mr. Clegg gives an account of the horrors of the lamp-lighters when they first beheld the burning gas, and how he was obliged to light the lamps himself for some time, on account of the fears of the people. Even such men as Sir Humphry Davy and Sir Joseph Banks were unable, for many years after this, to overcome the prejudices which existed in their minds concerning it; and they thought the scheme a wild and dangerous one. The public, however, soon became reconciled to it; and in 1814 the oil-lamps were removed from the streets of St. Margaret's, Westminster, and gas-lights were put into their places. This was the first parish that entered into a contract to have the streets lighted with gas.

In that same year the Allied Sovereigns came to this country; and as they were to be fêted and feasted in no ordinary manner, a great opportunity occurred for the use of gas, where no other means of illumination could be employed. On the ornamental water of St. James's Park a magnificent pagoda was erected; it was furnished with thousands of jets of gas, and in an instant, as if by magic, they all burst forth into flame, and gave the building the aspect of a brilliant fountain of fire. At one of the City feasts, the Guildhall was lighted up in a similar manner; and we are told by one of the journals of the time, that the light was "clear as summer's noon, but soft and undazzling as moonlight, forming a magnificent combination worthy the inuguration of the presiding citizen of the great city." Up to that time the gas was marvellously impure, and its fœtid odour proved an insurmountable barrier to the use of it in private houses. By and by, however, the attention of chemists began to be directed to this point; and as the processes of manufacture and purification were perfected, the use of gas became more and more general; so that in 1822 there were four great companies established in London, having forty-seven gasometers, supplied by 1315 retorts, which generated upwards of 397,000,000 cubic feet of gas annually, supplying about 61,000 private lamps, and 7,268 public ones. In five years this quantity had nearly doubled itself; and in ten years more it was doubled again, so that in the year 1837 it had acquired so much importance as to become a subject for parliamentary investigation. In that year a paper was laid before a Committee of the House of Commons, by Mr. Hedley; from which we gather, that for lighting London and its suburbs, a capital of £2,800,000 was employed. This yielded a revenue of £450,000, and furnished an annual supply of 1,460,000,000 cubic feet of gas. Twelve years after this, we are told by Mr. Croll, in his evidence before the Committee of the House of Commons on the Great Central Bill, that the consumption of gas in the metropolis, during the year 1849, was more than double that of the preceding estimate; for it amounted to 3,200,000,000 cubic feet annually, of which the City alone consumed 500,000,000. This was distributed to 2,678 public lights, and to a multitude of private consumers. The area of the metropolis is about sixty-six square miles, and that of the City one. In the former space there are, according to Mr. Barlow, about 2,400 miles of main-pipes, which run along 1,500 miles of streets; and in the latter there are about 110 miles of main-pipes, which light up 75 miles of streets. The surveyor to the Corporation states, in one of his reports, that the length of public way in the City is only 51 miles, and that the lamps average 54 to each linear mile, or 1 in every 33 yards. But perhaps the best estimate of the enormous extent to which this branch of industry is carried on, may be formed from a statement made by Dr. Hoffman, on the authority of Mr. Lowe, who is one of the oldest gas engineers of the present time. He says, that about 6,000,000 tons of coal are annually consumed in England in the manufacture of gas; and as each ton of coal does, on the average, produce about 10,000 cubic feet of gas, we have the almost incredible quantity of 60,000,000,000 cubic feet of gas produced yearly. And to this it may be added, that almost every town of upwards of two thousand inhabitants has its machinery for the manufacture of gas.

Action of Heat on Organic Matter.—As a preliminary to the study of gas-making, it is necessary that something should be known of the changes which occur when animal or vegetable matter is subjected to the action of heat. Chemists have shown that the effects vary with the temperature. At first, when the heat is not considerable, the matters evolved consist of aqueous vapour, organic acids, ammonia, and various combustible fluids which are soluble in water. In the second period, when the heat is somewhat higher, the products are carbonic acid, carbonic oxide, water, and a number of oleaginous or empyreumatic compounds, which are not soluble in water; and lastly, when the temperature is still higher, the products of the decomposition are hydrogen, marsh-gas, and sundry carbo-hydrogens, which retain their gaseous condition. In the case of non-nitrogenous bodies, as wood, resin, fat, oil, &c., the chief products of distillation are water, acetic acid, naphtha or wood-spirit, volatile oil, tar, paraffine, creosote, carbonic acid, carbonic oxide, olefiant gas, super-olefiant gas, marsh-gas, hydrogen, &c.; and when the substance contains nitrogen and sulphur, as is the case with coal, there are evolved ammonia, aniline, leukol, picoline, lutidine, &c., together with cyanogen, sulpho-cyanogen, and all the compounds just named. In every case there remains in the retort a quantity of carbonaceous matter, which goes by the name of coke, or *caput mortuum*.

Of the gases which are thus evolved, the most important are hydrogen, carbonic oxide, marsh-gas, olefiant gas, and various hydrocarbons, which give to gas its high illuminating power: all the others are positively injurious, and ought, therefore, to be got rid of before the gas is supplied to the public. An examination of the quality of these gases will readily convince us that they may be divided into three kinds—namely, the light-giving gases, the diluters, and the positive impurities. Of the *light-giving gases*, the following are the most important:—

(*a.*) *Olefiant gas* (C^4H^4): a compound that was discovered in the year 1795, by the associated Dutch chemists, and was so named from the property which it has of forming an oily-looking fluid when it combines with chlorine. It is an odorless gas, having a specific gravity of 0·97. It burns with a bright yellow flame, and consumes three times its bulk of oxygen, or nearly fifteen times its bulk of atmospheric air, producing twice its volume of carbonic acid. The gas is readily condensed by chlorine, bromine, or anhydrous sulphuric acid, and it is also absorbed to a slight extent by water.

(*b.*) *Other hydrocarbons*, as *Propylene* (C^6H^6), or the super-olefiant gas of Dalton and Henry, *Etherene* (C^8H^8), or the volatile gas of Faraday, and perhaps some others of a like atomic composition, are met with in most of the illuminating gases of commerce. These, like the last, consist of equal proportions of carbon and hydrogen. They are very condensable by chlorine, bromine, and fuming sulphuric acid, and they burn with a very bright sooty flame.

The *diluting gases* are marsh-gas, hydrogen, and carbonic oxide. These are important constituents of common gas, because they serve as the purveyors of the rich illuminating hydrocarbons, which could not be burnt alone.

(*a.*) *Marsh-gas*, or *light carburetted hydrogen*, is a compound of one atom of carbon and two of hydrogen (CH^2). It is about half as heavy as atmospheric air, and it burns with a bluish flame—that is, tipped with yellow. It consumes twice its bulk of oxygen, or nearly ten times its bulk of air; and it produces its own volume of carbonic acid.

(*b.*) *Hydrogen* is the lightest of all known substances. It is fifteen times lighter than atmospheric air. It burns with a pale blue flame, and consumes only half its bulk of oxygen, or two and a-half times its bulk of air; the sole product of its combustion being aqueous vapours.

(*c.*) *Carbonic oxide* (CO) is a little lighter than atmospheric air. It burns like the preceding, with a blue flame, and consumes only half its volume of oxygen. The product of its combustion is its own bulk of carbonic acid.

The *impurities of gas* are carbonic acid, ammonia, sulphuretted hydrogen, bisulphuret of carbon, tarry matter, and various compounds of cyanogen and sulphur.

(*a.*) *Carbonic acid* (CO^2) is a very heavy gas—its density being about 1·5. It is not only itself incombustable, but it has the power of checking the combustion of all inflammable gases. It is freely absorbed by lime and other alkalies. Water takes up about its own bulk of the gas.

(*b.*) *Ammoniacal gas* (NH^3) is about half as heavy as atmospheric air. It is not combustable, unless it is decomposed by the heat of some other burning body; and then the hydrogen of the gas burns in the usual manner. Ammonia is readily absorbed by water, and by solutions of acids and metallic salts. It is known by its communicating a red colour to turmeric paper, and by its fuming with muriatic acid.

(*c.*) *Sulphuretted hydrogen* (HS) is a most unpleasant-smelling compound; it is a little heavier than atmospheric air, and it burns with a pale-blue flame that evolves the odour of a burning match. When plenty of atmospheric air is present, the products of its combustion are water and sulphurous acid; but if the supply is limited, water alone is formed, and the sulphur is precipitated. The sulphurous acid quickly absorbs more oxygen, and becomes sulphuric acid,—a compound that exerts a most destructive influence on every kind of textile fabric. When sulphuretted hydrogen escapes into the air without burning, it discolours lead paint and tarnishes silver. On these accounts, sulphuretted hydrogen is regarded as one of the most injurious compounds of ordinary gas. It is absorbed by lime, and by the salts of iron, zinc, copper, and lead; and the test for it is a piece of white paper dipped in a solution of sugar of lead. On exposing paper while damp to the action of the gas, the lead-salt is quickly discoloured; and thus the smallest trace of sulphuretted hydrogen may be easily recognized.

(*d.*) *Bisulphuret of carbon* (CS^2) is even a more serious impurity than the last, for it not only produces the same acid compound by its combustion, but it is also more difficult of detection; and then, again, chemists are not yet acquainted with any process for the removal of this noxious body from the gas of commerce. All these circumstances give it an importance that it would not otherwise possess. Bisulphuret of carbon is, when pure, an oily-looking liquid that sinks in water. It evolves the unpleasant odour of putrid cabbage, and it boils at a temperature of 106° Fah.; it burns with a blue flame, and its vapour consumes twice and a half its bulk of oxygen, or nearly twelve and a half times its bulk of atmospheric air, producing twice its volume of sulphurous acid, and half its own volume of carbonic acid. This compound is best recognized by burning the gas and collecting the products, in which sulphurous or sulphuric acid will be discovered.

(*e.*) The *tarry matters of inflammable gas* are of a very complex nature; they appear to be held in solution by ammonia, and to be precipitated in the form of dark flakes, when the gas is made to pass through a vessel containing flints moistened with acid. It is very probable that these tarry matters are of an acid nature, and that, in their union with ammonia, they produce compounds that are sufficiently volatile to be suspended in the gas.

(*f.*) The *cyanogen compounds* are not likely to be found in the gas of commerce, for they are readily absorbed by the lime made use of in its purification. Cyanogen, hydrocyanic acid, and sulpho-cyanogen are the most important of these compounds.

The Manufacture of Gas.—In all cases, the destructive distillation of the organic substance which yields the gas is effected in an iron vessel called a retort, which is set in a furnace; and the gaseous products are purified by transmitting them through a series of vessels named condensers and purifiers. The details of the process vary with each particular gas, and consequently it is necessary to describe them under different heads.

Coal Gas.—The *apparatus* which is employed for the manufacture of coal-gas consists, first, of a *retort*, made of iron or clay, set in a furnace in such a manner that it may be heated throughout of a tolerably uniform temperature; an *outlet pipe* ascends from the end of the retort, and terminates in another pipe called the *hydraulic main*. This part of the apparatus is so constructed, that the pipe which delivers the gas from the retort dips down, to the extent of three or four inches, into the liquid matters contained in the hydraulic main. By this means the end of it is sealed or closed with a water-valve, and no gas can run back from the other parts of the apparatus into the retort during the time that the latter is being charged with coal. The *hydraulic main* is a large horizontal pipe, which runs from one end of the building to the other; it receives all the exit-pipes from the retort, and discharges its contents into a series of smaller pipes, which run to and fro or up and down in water or air, and so form a large cooling surface for the condensation of the liquid matters contained in the raw gas. Here it is that water and tar are deposited; and the apparatus is so constructed that the fluid matters run off, as fast as they are condensed, into a tank which is conveniently placed to receive them. This part of the apparatus is called the *condenser*. From the condenser the gas passes to the *purifiers*, which are vessels charged with lime and other substances that have the power of absorbing the various impurities of coal-gas. To assist the flow of gas through these vessels, an instrument called *an exhauster* is sometimes employed · it is a kind of air-pump worked by a steam-engine, which draws the gas away from the retorts, and so relieves them from that enormous amount of pressure that they would otherwise have to encounter while their gaseous contents are being forced on through the various obstructions that intervene between them and the gasometer. Leaving the purifiers, the gas passes into the large receiver or gasometer, where it is stored.

Materials employed in the Manufacture of Coal-gas.—Of the three varieties of coal known to chemists, the black or bituminous is the only one which is employed to any extent for the manufacture of gas. Lignite or brown coal occurs in too small quantity for this purpose; and glance-coal or anthracite is not sufficiently rich in hydrogen to be of any use to the gas-manufacturer. A small quantity of a peculiar bituminous shale, named boghead coal, has of late been employed in London and elsewhere; but its nature is not sufficiently well determined to enable us to say whether it is regarded as a coal or not.

The varieties of black coal are exceedingly numerous: in a general way, however, they may be divided into four kinds—namely, caking coal, which has the property of melting when it is heated, and so running together; splint coal, which is so named from its splintery fracture; cherry coal, which burns without caking at all; and cannel coal, which is exceedingly hard, compact, and bituminous. The first of these occurs abundantly in the neighbourhood of Newcastle, Northumberland, and Durham; the second in South Wales; and the last in Scotland and in Lancashire. Although these varieties of coal differ very considerably in their value for gas-producing purposes, yet regard must always be paid to the convenience or facility with which they are obtained; and hence we find that, in London, the coals of Newcastle, with certain cannels of Lancashire and Scotland, are employed. In Bristol and its neighbourhood, the coals of Gloucestershire and Wales are used; in Birmingham those of Staffordshire and Wigan; in Leicester, Nottingham, and Derby, the coals of Derbyshire; in Leeds and Sheffield, those of Yorkshire; in Liverpool, Salford, and Manchester, those of Wigan; in Edinburgh and the north of Scotland, the coals are chiefly derived from the Lothians and from Fifeshire; in Glasgow they are obtained from Lesmahago, Kelvinside, Wilsontown, &c.; and in Greenock they are procured from Monkland and Skaterig.

The temperature at which the carbonization of the coal is effected, and the manner in which the heat is applied, have an important influence on the quality of the gas and other products obtained. If the heat is too low, the quantity of gas produced is small, while that of the tar is large: on the contrary, if it is too high, the latter is sacrificed for the generation of the former. In the one case the gas is too rich in hydrocarbons, and in the other it is too poor. In practice, therefore, it is necessary to hit the happy medium; and it is generally thought that Newcastle coal requires a temperature of a dull, red heat (1300° Fah.) for its distillation, and that the richer cannels will bear a temperature of 1800° Fah., or a bright cherry red. The latter is a little above the melting-point of copper, and the former is a little below it.

Some idea may be formed of the relative value of these different kinds of coal by reference to the following table, which exhibits the proportions of volatile matter, coke, and ash produced by each description of coal, as well as the per-centage amount of sulphur contained in the coal, the coke, and the gas. The coals are arranged in the order of their gas-producing properties; and it will be seen that the amount of volatile matter ranges between 23 and 68 per cent., and that the quantity of sulphur contained in the volatile matter is from 1 to 5 per cent.:—

Name of Coal.	Vol. Matt.	Coke.	Ash.	Sulphur in Coal.	Sulphur in Coke.	Sulphur in Vol. Matt.
Boghead	68·4	31·6	22·8	0·53	0·08	0·45
New Brunswick cannel	66·3	33·7	0·6	0·07	0·00	0·07
Kirkness	60·0	40·0	13·5	1·40	0·58	0·82
Capeldrac	54·5	45·5	10·5	0·65	0·20	0·45
Old Wemyss	52·5	47·5	15·1	1·30	0·60	0·70
Staffordshire cannel	50·0	50·0	2·9	1·30	0·52	0·78
Lesmahago	49·6	50·4	9·1	2·25	1·14	1·09
Knightswood	48·5	51·5	2·4	1·10	0·61	0·49
Arniston	45·5	54·5	4·2	1·70	0·95	0·75
Heathern (Stafford)	42·9	57·1	1·8	1·50	0·70	0·80
Ruabon main (N. Wales)	41·5	58·5	1·0	0·85	0·45	0·40
Stavely (Derby)	40·9	59·1	2·7	1·20	0·80	0·40
Radstock (Somerset)	38·3	61·7	3·5	3·10	1·80	1·30
Silkstone (Yorkshire)	38·0	62·0	2·6	1·10	0·60	0·50
Blenkinsopp	38·0	62·0	5·1	1·60	0·80	0·80
Wigan (Lancashire)	37·0	63·0	3·0	1·25	0·60	0·65
Mortomly (S. York)	37·0	63·0	1·6	1·10	0·60	0·50
Elsecar (Yorkshire)	37·0	63·0	1·1	1·20	0·63	0·57
Ramsay (Newcastle)	36·8	63·2	6·6	1·75	0·94	0·81
Hastings' Hartley	36·5	63·4	2·0	0·95	0·50	0·45
South Tyne	36·3	63·7	3·9	2·10	1·10	1·00
West Hartley	35·8	64·2	4·7	1·10	0·60	0·50
Grigleston Cliff	35·6	64·4	1·6	1·40	0·75	0·65
Gosforth	35·0	65·0	1·0	1·10	0·50	0·60
Soap-house Pit	35·0	65·0	0·8	0·75	0·40	0·35
Nailsea (Somerset)	34·9	65·1	3·0	2·85	1·50	1·35
Leverson's Wallsend	34·9	65·1	4·9	1·30	0·65	0·65
Arley (Lancashire)	33·7	66·3	3·6	1·20	0·60	0·60
Lockgelly cannel	33·5	66·5	13·1	0·75	0·25	0·50
Woodthorpe (S. York)	33·1	66·9	10·5	1·20	0·70	0·50
Pelton Main cannel	31·5	68·5	9·4	0·95	0·49	0·46
Washington	31·3	68·7	2·2	1·30	0·67	0·63
Pelaw main	30·3	69·7	2·6	1·20	0·70	0·50
New Pelton	30·2	69·8	1·8	1·10	0·56	0·54
Coal-pit Heath	30·1	69·9	5·8	4·10	2·20	1·90
Garesfield	29·4	7[illegible]·6	1·0	0·85	0·40	0·45
Dean's Primrose	29·3	70·7	2·4	1·40	0·71	0·69
Urpeth	28·7	71·3	1·4	1·00	0·60	0·40
Pelton main	28·4	71·6	1·4	1·10	0·62	0·48
South Peareth	27·8	72·2	1·8	1·20	0·60	0·60
Cumberland	25·6	74·4	1·4	1·10	0·60	0·50
Rhonda (S. Wales)	23·1	76·9	2·1	2·20	1·10	1·10

With regard to the manner in which heat is to be applied, it may be said, that, within certain limits, the more quickly the heat is applied, the greater the quantity and the better the quality of the gas obtained; for too slow a heat generates volatile matter, which condenses in tar; and too quick a heat decomposes the gas, and destroys its illuminating powers. Lastly, it may be remarked, that the duration of the heat ought not to exceed five hours; for at the expiration of that time the gases which are evolved are of little use for illuminating purposes, and the sulphur which is contained in the coke begins to distil over as bisulphuret of carbon, which is a most objectionable impurity.

Purification of Gas.—This is effected in various ways; some of the contrivances being mechanical in their action, and others chemical. When the volatile matters quit the retort, they consist of aqueous vapour, tar, olefiant gas, and other rich hydrocarbons, light carburetted hydrogen, hydrogen, carbonic acid, carbonic oxide, sulphuretted hydrogen, sulphuret of carbon, cyanogen, and ammonia. Only a few of these are required for illuminating purposes, and the rest must be got rid of. Foremost in the order of purification is that which takes place in the hydraulic main. There the most condensable of the empyreumatic vapours are deposited, and they run away into the neighbouring tank as a most foetid mixture of tar and watery matters. Next to this is the condenser—an apparatus which exposes the gas to a large extent of cooling surface. We have already described the form of the apparatus, and said that it causes the condensation of the liquifiable matters contained in the gas. It precipitates tar, water, and ammonia, in combination with sulphuretted hydrogen, carbonic acid, and cyanogen. In some cases the gas is made to pass through a vessel containing pieces of coke, over which a stream of water is constantly running. The gas enters at the bottom of the vessel, and, having made its way between the fissures of the coke, it escapes at the top. A stream of water runs over the coke in an opposite direction; and thus the gas is, as it were, washed and scrubbed by the two materials with which it is brought into contact. This apparatus is, therefore, very appropriately named a *scrubber*. The only impurities now left in the gas are ammonia, carbonic acid, sulphuretted hydrogen, cyanogen, and bisulphuret of carbon. These can only be removed by the aid of chemical absorbents; and the gas is, therefore, made to pass through a set of vessels which are named, *par excellence*, the purifiers. These contain milk of lime, or lime that has been recently slaked. In the former case it is named a wet-lime purifier, and in the latter a dry. In both cases the gas enters at the bottom of the vessel, and it is either distributed in a stream of small bubbles through the liquid, or else it courses its way between the moist particles of the recently slaked lime. By this contrivance carbonic acid, cyanogen, and sulphuretted hydrogen are extracted from the gas; these combine with the lime and produce a most unpleasant-smelling compound, which is technically termed *blue-billy*. In consequence of the loss of ammonia by this process of purifying, and the disgusting nature of the refuse materials, a number of patents have been taken out at various times for the purification of coal-gas by other means than that of lime alone. The oxides of iron, in various conditions, have been patented by Messrs. Croll, Hills, Laming, and Lowe; the common salts of lead have been patented by Mr. Lowe and Mr. Losh; oxychloride of antimony by Mr. Kirkham; sulphate of iron, with common salt and charcoal, by Mr. Cormack; sulphate of lime and magnesia by Mr. Hills; superphosphate of lime by Mr. Johnson; muriate of lime by Mr. Laming; muriate of manganese by Mr. Croll; and clay by Mr. Bowditch. Indeed, it would appear as if all the refuse matters of the arts had been successively tried and patented, in the hope of their becoming a means of extracting the impurities from coal-gas. In most cases these substances merely absorb ammonia, and in a few instances they take up sulphuretted hydrogen also. Quitting the purifiers, which are charged with one or more of the preceding compounds, the gas enters the gasometer, and is in the condition in which it is to be supplied to the public.

The products of these operations are more or less valuable in every stage of the process. The coke which is drawn from the retort after the extraction of the gas meets with a ready sale; the ammoniacal liquor which floats upon the tar in the tanks of the condenser and hydraulic main contains enough ammonia to make about sixteen ounces of sulphate, or twelve and a half of carbonate, or eleven and a half of muriate, from every imperial gallon; and as each ton of Newcastle coals produces from ten to twelve gallons of this liquor, there is a large amount of valuable matter generated in the process. The tar, also, is made to give up its wealth by the all-powerful aid of chemistry. As it leaves the manufactory, it is a dark-coloured, heavy liquid, of a most unpleasant odour; but by distillation in rude iron boilers it furnishes naphtha for lamps, dead-oil or creosote for railway timbers, and pitch or asphaltum for a variety of purposes. When the richer varieties of cannel coal have been used for the generation of gas, the tar also contains paraffine, which has already been described; and it likewise yields by distillation an oil which is largely employed for lubricating machinery. Within the last few years a number of patents have been taken out for the management of coal-tar; but as yet we have only begun to have an insight into the nature of the many valuable compounds that are locked up in it. Nevertheless, three classes of bodies have already been discovered in coal-tar; namely, neutral principles, acid substances, and alkaline matters. Among the first are benzole ($C^{12}H^{6}$), toluole ($C^{14}H^{8}$), cumole ($C^{18}H^{12}$), cymole ($C^{20}H^{14}$), naphthaline ($C^{20}H^{8}$), paranaphthaline ($C^{30}H^{12}$), pyrene ($C^{15}H^{6}$), chrysene ($C^{12}H^{6}$), paraffine ($C^{20}H^{21}$), and various liquid hydrocarbons, which have not yet been isolated. Among the acid substances, the most important is the acid of creosote, or carbolic acid ($C^{12}H^{6}O^{2}$); and of the alkaline matters there are pyridine ($C^{10}H^{5}N$), picoline ($C^{12}H^{7}N$), and its homologue, aniline ($C^{12}H^{7}N$), lutidine ($C^{14}H^{9}N$), leucoline ($C^{18}H^{7}N$), a new base ($C^{16}H^{11}N$), and parvoline ($C^{18}H^{13}N$): in addition to which there are, in all probability, other compounds which are isomeric with the preceding. Now the great and interesting fact which has been developed by the study of these compounds is, that they all contain but one element of nitrogen, and that, with one or two exceptions, they rise by regular gradations of two of carbon and two of hydrogen: first we have $10 + 5$, then $12 + 7$, then $14 + 9$, and so on. Besides which, they are all isomeric, or have exactly the same composition with another series of bases called the aniline series. To the chemist these facts are of the greatest importance, not merely because of their individual interest, but because of their influence on the philosophy of science. At one time it was thought that whenever two things differed in their chemical and physical properties, they must be different also in their composition; and when Professor Faraday showed that one of the constituents of the fluid obtained by the condensation of oil-gas was identical, in its chemical composition, with another body (olefiant gas), notwithstanding that it differed from it in all its physical properties, chemists were hardly able to comprehend it; but ere long the fact was recognized as one of the most common occurrences in the whole range of chemistry. And so it is, an examination of the most insignificant of materials will often furnish results that not only affect the ancient landmarks of science, but also open up a new way to the practice of industry and the acquirement of wealth. Who, for example, could have supposed that so disgusting a liquid as coal-tar—a liquid which a few years since the manufacturers of gas knew not how to dispose of—would, through the golden key of chemistry, be made the means of changing the aspect of chemical science, and of opening up new and profitable branches of industry? Take the crude tar and submit it to distillation at a low temperature—the temperature of boiling water: it yields a light volatile oil, which is commonly called naphtha. This consists in great part of a valuable ethereal liquid, which we have already described under the name of benzole,—a liquid which may be used for burning in lamps, for dissolving resins, and for manufacturing a rich perfume (nitro-benzole), which has the delicious odour of the essential oil of bitter-almonds. By continuing the distillation at a somewhat higher temperature, there passes over an oil which is heavier than water. This is called dead-oil; it contains the naphthaline, paraffine, creosote, and various liquid hydrocarbons, which have not been sufficiently well studied, but which perhaps contain mines of chemical wealth. The dead-oil is largely employed for the preservation of timber, and for lubricating machinery: and lastly, that which remains in the still is sold as asphalt or pitch. As might be expected, there is a difference in the quality of these products, according as the tar is obtained from common Newcastle coal, or from the richer sorts of cannel.

Of the other impurities or products of gas-making, cyanogen is the most important; already it has been extracted from the impure gas, and converted into Prussian blue. It is said that a ton of Newcastle coal will yield enough cyanogen to produce seven pounds of Prussian blue—a quantity that will, at the present market-price of the pigment, almost cover the original cost of the coal.

The mode of obtaining this compound is very simple. When tho raw or impure gas is purified by hydrated oxide of iron, according to the patents of Croll, Laming, and Hills, the cyanogen combines with the iron and produces the pigment in question. But when thus made, it is largely contaminated with sulphuret of iron and other impurities. These may be got rid of by washing the mixture with dilute sulphuric or muriatic acid. Or if the iron compound is treated with a solution of potash, it gives up its ferro-cyanogen, and produces prussiate of potash, which is an equally valuable compound.

The following table, which has been constructed from the experiments of Messrs. Barlow and Wright, will afford some idea of the relative proportions of gas, tar, ammoniacal liquor, and coke, furnished per ton by different varieties of coal:—

Coal.	Gas in cubic feet.	Tar in lbs.	Ammo. liquor in lbs.	Coke in lbs.
Pelton main	9650	102	102	1,543
Newcastle cannel	9830	98	60	1,426
Wigan (Ince Hall)	10850	248	162	1,332
Luchgelly cannel	8381	225	340	1,245
Boghead.............	13340	733	0	715
Lesmahago	10779	598	4½	1,077
Ramsay cannel	9016	295	6½	1,435
Derbyshire deep main ..	9400	219	179	1,335
Wemyss	10584	210	very little	1,156

Tests for the Impurities in Coal-gas.—Notwithstanding that so much trouble is taken with the purification of coal-gas, yet it is found that a greater or less proportion of the several noxious compounds already described, will escape absorption, and will find their way into the street mains. The most important of these are ammonia, carbonic acid, sulphuretted hydrogen, bisulphuret of carbon, and tarry matter.

The first of these is objectionable from the circumstance that it attacks the fittings, corrodes the meters, and fixes the stop-cocks; besides which, it has the property of holding tar in suspension. Ammonia ought not to exist in coal-gas to a greater extent than one part in about 50,000: that is, 100 cubic feet of gas ought not to contain more than about 3·5 cubic inches, or rather more than half a grain, of ammoniacal vapour. Anything approaching to this quantity may be readily discovered by means of turmeric paper, which is immediately reddened by the impure gas.

The presence of carbonic acid may be known by collecting a bottleful of the gas and shaking it up with a little lime-water; if the impurity be present, the lime-water will be rendered milky. The great objection to carbonic acid is, that it reduces the illuminating power of the gas, and thus lowers its value. Mr. Wright and Mr. Lewis Thompson say, that every one part of carbonic acid in a hundred of gas, reduces its illuminating power to the extent of eight or ten per cent.

Sulphuretted hydrogen may be discovered by a solution of sugar of lead, a little of which ought to be dropped on a strip of white paper, and then held in the gas for a period of not less than ten minutes or a quarter of an hour. If the paper becomes discoloured, sulphuretted hydrogen is present. There are several reasons why this impurity should not exist in coal-gas: it gives to the gas a feted odour; it tarnishes silver, and destroys the beauty of paint; and in the act of burning, it generates a corrosive compound, which acts injuriously on books, linen goods, and other textile fabrics.

Bisulphuret of carbon is not so easily detected, for the gas must be burnt under a platinum rosette, and the products of combustion collected in a vessel containing a little ammonia. Mr. Wright, of the Western Gas Company, has contrived an apparatus for this purpose. Having consumed about twelve cubic feet of gas at the rate of half a cubic foot an hour, it will be found that six or seven ounces of water will have condensed in the receiver. This is to be treated with a solution of nitrate of baryta, that has been rendered acid by a little aqua-fortis. If, in the course of a few hours, a white powder settles to the bottom of the liquid, we may be sure that bisulphuret of carbon was present in the gas; and if we collect the precipitate and weigh it, we shall be able to determine the quantity of impurity present: for every 234 grains of sulphate of baryta, represent 38 grains, or nearly 46 cubic inches, of the vapour of bisulphuret of carbon. By proceeding in this way we find that 100 cubic feet of coal-gas yield from 50 to 300 grains of sulphate of baryta—quantities that represent from 8·1 to 48·6 grains of bisulphuret of carbon. The presence of this impurity in coal-gas is a most serious affair: for it has been shown by Dr. Letheby in several of his Reports to the Corporation of London, that bisulphuret of carbon, in the act of burning and oxydizing, forms sulphuric acid; a great portion of which escapes in a corrosive form, and does enormous damage to every kind of textile fabric. He states that the books in almost every library in the kingdom where gas is used, are falling to pieces from the action of this acid upon the covers; and he makes reference to the libraries of the Athenæum Club-house, the London Institution, the Royal College of Surgeons, the Portico Library at Manchester, and that of the Literary Society at Newcastle-upon-Tyne, for examples of the mischief done. In most of these places, the injury has been so great that a remedy has been called for. This remedy consists in burning the gas in such a way, that the products of combustion shall be carried away as soon as they are generated.

As regards the quantity of sulphuric acid which is produced in this manner from bisulphuret of carbon, we may say that there is some discrepancy of opinion. Mr. Lewis Thompson states that coal-gas rarely contains less than the one-thousandth of its bulk of bisulphuret of carbon; and if so, 100 cubic feet of the gas can rarely produce less than 298 grains of anhydrous sulphuric acid. In another place he states that he has never obtained less than 40 grains of such acid from 100 cubic feet of gas. On the other hand, Dr. Letheby asserts that he rarely obtains more than 20 grains of the acid. But let the quantity be what it may, it is evident that mischief must arise from its presence, and that the attention of chemists and gas-manufacturers ought to be especially directed to this subject. The quantity of this impurity is small when the gas has been generated at a low heat; but it is large when the temperature of the retort has approached a full red, or when the charges have been kept in beyond five hours. If, therefore, no means can be adopted for the removal of the impurity after it has once been formed, it is manifest that care should be taken not to produce it.

Tarry matter is held in suspension in coal-gas by means of ammonia; consequently, if we pass the gas through a small bottle or tube containing fragments of flint, moistened with dilute sulphuric acid, we shall absorb the ammonia and arrest the tar. When coal-gas, containing much tar in suspension, escapes through the fissures in the street-pipes, it impregnates the soil of the neighbourhood, and gives it a most offensive odour.

Atmospheric air is sometimes present in coal-gas when the exhauster has been doing its work too energetically, or when there have been leakages in the vessels or pipes between the retorts and the exhauster. This is recognized by the blueness or thinness of the flame, and by its low illuminating power.

The Analysis of Coal-gas is rather a complicated undertaking; though a good general idea may be formed of its composition by the following process:—Collect a quantity of gas in a graduated tube over quicksilver; introduce a solution of caustic potash, and agitate it with the gas for some minutes; then allow the tube to stand for a short time, and observe how much carbonic acid has been absorbed. After this has been done, pass up a concentrated solution of pyrogallic acid in potash, or, better still, a small quantity of the powdery crystals of pyrogallic acid itself; shake the tube again, and having allowed it to stand for a few minutes, read off the bulk of oxygen that has disappeared; transfer the gas to another tube over water, and by means of a syringe, or other contrivance, introduce a small quantity of bromine, or of strong solution of bromine; shake the tube for a minute or so, and observe that the bromine is in sufficient quantity to give the gas an orange-red colour; after the lapse of four or five minutes, pass up a solution of potash and shake again. In this way the excess of bromine will be absorbed; and on allowing the tube to stand for a short time, the amount of condensable hydrocarbon may be determined by the loss in bulk. Transfer the gas to another tube, and agitate it with a solution of dichloride of copper in muriatic acid (this is made at once by mixing equal parts of black oxide of copper and recently precipitated copper, with muriatic acid). After a few minutes, the solution is to be withdrawn and the gas washed with potash; the loss in bulk indicates the quantity of carbonic oxide present. Lastly, a portion of the residual gas is to be transferred to an eudiometer, and mixed with about twice its bulk of oxygen; and the mixture is to be fired by the aid of an electric spark. After standing for a few minutes, the loss in bulk is to be observed; a solution of caustic potash is then to be passed up into the gas, and the absorption of carbonic acid noted. This indicates the amount of light carburetted hydrogen present; and then by subtracting twice this volume from the total amount of diminution caused by the detonation, we obtain a number, two-thirds of which represent the hydrogen of the gas. Lastly, the residual gas, from which the portion for the oxygen experiment was taken, is to be mixed with about four times its bulk of pure chlorine, and exposed for some hours to daylight, or for a moment or two to sunlight, and then washed with potash—the residue is nitrogen. In this way we may obtain an estimate of the proportions of the chief constituents of coal-gas. These, however, vary to the following extent:—

Light carburetted hydrogen	from	35 to 52	per cent.
Hydrogen	,,	25 to 52	,,
Carbonic oxide	,,	7 to 9	,,
Carbonic acid	,,	0 to 4	,,
Oxygen	,,	0 to 2	,,
Nitrogen	,,	0 to 8	,,
Condensable hydrocarbons	,,	3 to 20	,,

The approximative or commercial value of coal-gas is determined in several ways: thus—

1st. *By means of the Photometer.*—This we have already alluded to when speaking of the general phenomena of light; and it is only necessary to say here that the methods employed are four-fold—namely, Count Rumford's plan, with shadows; Ritchie's, with his instrument that has two reflecting surfaces and a screen in a dark chamber; Wheatstone's, which consists of a mechanical contrivance, whereby a silver bead is made to revolve in such a manner as to produce a geometrical figure with two outlines; and, lastly, the plan usually employed is that of Bunsen's, with a waxed screen and a graduated rod—a description of which has already been given. Some doubt exists as to the kind of illuminating standard which ought to be adopted. Originally the standard was a mould candle of six to the pound; but there are so many objections to its use that it has long been discontinued. Dr. Frankland employs a composite candle, Dr. Fyfe prefers one of wax; and the standard which is specified in most of the Acts of Parliament relating to the subject, is a wax candle of six to the pound, burning at the rate of 120 grains per hour. In general, however, it is found that there are more irregularities with the combustion of wax than with sperm: and, consequently, the latter is now almost always employed. Sometimes the comparison is made with one candle; Dr. Letheby uses two, and Mr. Evans employs three. A jet of gas composed of hydrogen and olefiant gases, mixed in the proportion of nine of the former to one of the latter, has been proposed as a standard of constant value; but the use of it is very inconvenient: and, lastly, Mr. Lewis Thompson has suggested the employment of paraffine.

Finally, it ought to be stated that whenever the quality of gas is estimated by any of these methods, it ought to be consumed from the burner or jet which is best fitted for its combustion. If this is not attended to, a discrepancy to a large extent may arise between two different experimenters. As a rule, common gas requires a larger aperture for combustion than cannel; and high glasses, or chimneys, are apt to lower the illuminating power of the former, and to raise that of the latter. Different experimenters have exhibited different fancies with regard to this part of the subject: for example, Mr. Wright prefers a single jet, the one-eighth of an inch in diameter, for his investigations; Dr. Fyfe makes use of a Winfield or Aberdeen burner; and in London, the burner fixed by Act of Parliament is an Argand of sixteen holes, with a seven-inch chimney, consuming five cubic feet per hour. There is no doubt, however, that in many cases a fish-tail or a bat's-wing will afford the best light for testing purposes. We append the following table to show how much the character of the burner affects the quality of the results obtained:—

Burner.	Consumption per hour in cubic feet.	Illuminating power.	Illuminating power per foot.
Jet five inches high	1·00	1·00	1·00
Small fish-tail	1·98	2·89	1·45
Large ditto	2·60	4·00	1·53
Small bat's-wing	3·00	4·40	1·46
Large ditto	4·60	8·40	1·87
Argand of forty holes	4·50	7·84	1·74

These results were obtained by Dr. Fyfe with cannel gas; and they show that the large bat's-wing produces a flame that, for equal consumption, is nearly twice as powerful as that with the single jet.

Again, the quantity of gas consumed per hour in the same burner will affect the results; thus—

Burner.	Consumption per hour in cubic ft.	Power of gas per foot.
Argand, with seventy-two holes	7·0	5·57
" " "	5·0	6·60
" " "	3·3	3.40

From which is is manifest that in ascertaining the illuminating power of gas, great judgment is necessary, both in the selection of the burner and in the rate of consumption, in order to obtain fair and proper results.

2nd. *The Chlorine test* is very much appreciated by Dr. Fyfe. It was originally proposed by Dr. Henry, and in his hands it afforded very accurate results. The objection to the test is its inconvenience; for chlorine takes a long time to prepare, and we are never certain of its being pure. Besides which, it is an unpleasant gas to inhale; and, escaping into the laboratory, it produces the most serious injury to the brass and iron-work of chemical apparatus. The mode of conducting the experiment is this:—A quantity of gas is to be let up into a graduated tube over water; the tube is then to be covered so as to exclude light, and chlorine is to be passed up into it. After standing for ten or fifteen minutes in the dark, the excess of chlorine is to be absorbed by potash, and the amount of absorption read off. The larger the quantity absorbed, the better the gas. This will range from three to twenty per cent. The matters absorbed by the chlorine are the condensable hydrocarbons, which are the illuminating principles of the gas.

3rd. *The Bromine test.*—Many years ago M. Balard showed that bromine had the power of absorbing olefiant gas, and that in this respect, as in most others, it was like chlorine. Lately Mr. Lewis Thompson has taken advantage of this property, and has made it the means of discovering the quality of coal-gas. The reactions of bromine on gas are exactly the same as those of chlorine; but it has an advantage over the latter, in the circumstance that it is much more manageable, that it is more likely to be pure, and that the admission of light does not affect the results. In manipulating with this body we fill a graduated tube, called a Cooper's tube, with gas, and then pour into the shorter leg of the instrument a small quantity of a saturated solution of bromine in water, taking care to use enough to give the gas an orange-red colour. After the mixture has been shaken, the tube is allowed to stand for about ten minutes, and then the excess of bromine is to be absorbed by means of potash; after which, the amount of absorption is noted. As in the last case, this will range between three and twenty per cent. according to the quality of the gas.

4th. *The Sulphuric Acid test.*—Professor Faraday long since observed, that when concentrated sulphuric acid was brought into contact with the condensable hydrocarbons, it speedily absorbed them. Relying upon this fact, Professor Bunsen has recommended that fuming or anhydrous acid should be employed for the purpose of ascertaining how much of these agents is present in coal-gas. Messrs. Leigh and Frankland have spoken well of the results obtained in this manner; but however successful the process may be in their hands, it is open to many fallacies, and cannot therefore be recommended to the unskilful operator. The mode of experimenting is this:—The gas is to be collected in a graduated tude over mercury; and then a piece of coke or pumice-stone, fastened to a platinum wire and moistened, or rather saturated, with the acid, is to be passed up into the gas; after remaining in contact with it for ten minutes or a quarter of an hour, the coke is to be withdrawn; and as a small quantity of sulphurous acid will have been formed by the action of the coke on the mercury, the gas is to be washed with a little potash, and then the amount of absorption noted. Sulphuric acid does not, however, attack all the hydrocarbons; for it is found that chlorine or bromine will effect a further condensation after the action of the acid. This, with other circumstances, renders the process objectionable.

5th. *The Explosion test.*—Dr. Henry noticed that there was a direct relation between the value of a gas for illuminating purposes, and the quantity of oxygen required to burn it, or of carbonic acid produced thereby. In fact, as the illuminating power of any gas is dependent on the quantity of carbon contained in a given bulk of it, it follows that the products of its combustion must furnish a sure indication of its value. This will be manifest from the following table:—

One volume of	Oxygen required to burn.	Carbonic acid produced.
Marsh gas (CH^2)	2 volumes.	1 volume.
Olefiant gas (C^4H^4)	3 ,,	2 ,,
Superolefiant gas (C^6H^6)	4·5 ,,	3 ,,
Faraday's gas (C^8H^8)	6 ,,	4 ,,
Bicarburetted hyd. (C^6H^3)	7·5 ,,	6 ,,

So that if we mix a known quantity of any gas with about three times its bulk of oxygen, and explode them in an eudiometer by means of electricity, or make them combine by the aid of spongy platinum, as Dr. Henry suggested, the amount of oxygen consumed, and of carbonic acid produced, will serve as indications of the quality of the gas. Dr. Henry found that the best description of coal-gas requires two and a quarter times its bulk of oxygen for combustion, and gives one and a quarter of carbonic acid; while the worst gas of his time took only eight-tenths of its bulk of oxygen, and gave but three-tenths of carbonic acid. The amount of carbonic acid produced is to be determined in the usual way by means of liquor potassæ.

6th. *The Specific Gravity test.*—This is founded on the fact that the rich hydrocarbons are much heavier than the poor ones; for example, if a given bulk of marsh gas, or light carburetted hydrogen, weighs 10 grains, the same bulk of olefiant gas will weigh 17½ grains; and in the case of the other hydrocarbons, the increase in weight is still greater. A knowledge of this fact will enable us to ascertain the value of any description of gas. We take a glass globe, or flask, fitted air-tight to a stop-cock, and exhaust it with great care, by means of an air-pump; then let in pure and dry hydrogen, and again exhaust. Do this a third or even a fourth time, so as to get the flask as empty of air as possible; then weigh in a delicate balance, and note the amount: pure and dry atmospheric air is now to be admitted, and the flask is to be weighed again. In this manner we ascertain how much of pure dry air, at a temperature of 60° Fah. and a pressure of 30 of the barometer, it contains. When we wish to take the specific gravity of any gas, the globe is to be exhausted as before, then filled with the gas, and weighed; corrections are to be made for any abnormal difference of temperature or pressure; and then we say, as the weight of the vesselful of air is to 1, so is the weight of the gas to its specific gravity. In practice it will be found convenient to have a globe with two stop-cocks, one opposite the other; so that after the first exhaustion and weighing, the globe can be easily filled with gas without the aid of an air-pump, by simply allowing the gas to pass through it for about a quarter of an hour. Mr. Wright has constructed an apparatus which still further simplifies this calculation. It consists of an oiled silk balloon that holds 1000 cubic inches of gas; and as coal-gas is lighter than air, he determines its specific gravity by ascertaining the number of grains which the balloon will carry up. A book that accompanies the apparatus contains instructions for the management of the experiment. The specific gravity of coal-gas ranges between 390 and 750. The former is about the weight of the worst gas from Garefield coals, and the latter of the best from Boghead cannel; a good average of specific gravity is 450. In conducting experiments of this kind, it must be ascertained that the gas does not contain carbonic acid, carbonic oxide, or atmospheric air; for if it does, the specific gravity of the gas is sure to be high, notwithstanding that the illuminating power may be very low.

Before we leave this part of the subject, it may be remarked, that if the specific gravity of a gas is taken before its condensation by bromine, and then again afterwards, the difference in weight will afford a means of ascertaining the specific gravity of the condensed portion; and if this be multiplied by the amount of condensation, we obtain a number that represents very nearly the illuminating power of the gas in sperm candles, as it is usually expressed. For example: a gas of specific gravity 447, has a condensation of 5 per cent., and the residual gas has a specific gravity of 328. Now since 100 cubic inches of the former weigh 13·63 grains, and 95 cubic inches of the latter 9·5 grains, the 5 cubic inches of the condensed portion must have weighed 4·13 grains, and it must have had a specific gravity of 2·7. This, multiplied by 5, the amount of condensation, gives 13·5 as the illuminating power of gas. Experiment showed it to be 14.

7th. *The Durability test.*—Dr. Fyfe, who is an authority in matters of this description, is accustomed to estimate the value of a gas not only by noting its amount of condensation with chlorine, but also by observing the time that it takes to burn a given bulk of it from a jet of a given size, with a flame of a given height. The jet which he employs has an aperture of the one-thirty-third of an inch in diameter, and the flame is four inches in height. The first of these tests he calls the *quality* test, and the latter the *durability*. "I consider," he says, "both of these circumstances absolutely necessary; for though some have insisted only on the one, and others on the other, yet, unless both be taken into account, we do not arrive at the true *value* of the gases, and, consequently, cannot compare one with another for the purpose of illumination." He thinks it possible that two gases may afford by combustion the same amount of light for the same height of flame, but that one may burn away half as fast again as the other;

and, consequently, if no regard is paid to this circumstance, there will be a false estimate of their relative values. His mode of amalgamating these two powers is to multiply the percentage amount of condensation by the durability or time required to burn a cubic foot; and in this way he obtains a number that may be said to represent the true value of the gas. Suppose that one gas, which he takes as a standard, has a condensation of 4·33, and a durability of 50·5 minutes—these multiplied together make 218·7, which may be called the value of the gas. Another gas has a condensation of 7·55, and a durability of 57 minutes; these multiplied together give a value of 430·3. Now if we call the standard number of the former 1, that of the second will be 1·95; and thus we obtain their relative values. The following table is constructed on this principle:—

Gas from	Condensation by chlorine.	Durability of a cubic foot.	Relative value.
English caking-coal (Newcastle)	4·33	50′ 30″	1·00
Peareth and Pelton	6·50	50′ 40″	1·50
Yorkshire Parrot	7·66	52′ 30″	1·85
English cannel (Wigan)	7·55	57′ 0″	1·93
Ramsay Parrot	12·00	62′ 0″	3·40
Midlothian	13·00	60′ 0″	3·56
Lesmahago	17·10	65′ 0″	5·07
Scottish Parrot	15·00	80′ 0″	5·46
Wemyss	19·50	75′ 0″	6·69
Kirkness	20·70	80′ 0″	7·75
Boghead	22·40	81′ 3″	8·32

It will be noticed that when the value of a gas is tested in this manner, it indicates a higher quality than we are accustomed to obtain by means of the photometer; but this Dr. Fyfe regards not as an error in his process, but rather as an evidence that we do not take the best means to burn the gas to the best advantage; and consequently that the illuminating power is, in the case of the richer cannels, a little below its true value.

As a corollary to the preceding, we append a table which shows the quantity of gas furnished by different varieties of coal, together with the specific gravity of the gas, its illuminating power in sperm candles of 120 grains each, its percentage amount of condensation by bromine, and its actual value in sperm candles. This table has been compiled from the results obtained by Mr. Evans, Mr. Thompson, Dr. Letheby, and others.

Coals.	Cubic feet of gas per ton.	Illuminat. power.	Specific gravity.	Condens. by Brom.	Value in grs. of Sperm.
Boghead cannel	15,000	37·75	752	30·0	113,250
Lesmahago No. 1	13,500	27·10	642	16·0	73,170
Wemyss	14,300	24·50	580	14·0	70,070
Lesmahago No. 2	13,200	24·80	618	17·0	65,472
Capeldrase	14,400	19·75	577	16·5	56,880
Armiston	12,600	22·50	626	17·0	56,600
Kirkness	12,800	21·20	562	10·2	54,272
Knightswood	12,200	19·00	550	9·5	50,160
Wigan (Ince Hall)	11,400	20·00	528	11·5	45,600
Ramsay	10,300	21·40	548	12·5	44,084
Pelton cannel	11,500	18·50	520	10·5	42,750
Leverson cannel	11,600	18·00	525	10·0	41,720
Washington cannel	10,500	18·00	500	10·5	37,800

Continuation of Table.

Coals.	Cubic feet of gas per ton.	Illuminat. power.	Specific gravity.	Condens. by Brom.	Value in grs. of Sperm.
Brymbo main	10,500	15·00	540	6·8	31,500
Pelton main	11,000	14·00	430	4·5	30,800
Dean's Primrose	10,500	12·00	430	5·0	28,350
Washington	10,000	14·00	430	5·0	28,000
Pelaw	11,000	12·75	420	4·5	28,050
Brymbo cannel	6,650	20·00	504	11·5	27,160
Blenkinsopp	9,700	14·00	450	6·0	27,160
Leverson	10,800	12·50	425	4·0	27,000
West Hartley..........	10,500	12·50	420	4·2	26,250
Hastings' Hartley......	10,300	12·50	421	4·3	25,750
New Pelton	10,500	12·00	415	4·8	25,200
Garefield	10,500	11·50	398	3·8	24,150
Gosforth..............	10,000	12·00	402	4·0	24,000

Oil Gas.—Originally this was the gas most generally in use for illuminating purposes; but the cost of its manufacture was found to be too great for its continued employment.

As far back as the year 1805, Dr. Henry published an account of some experiments which he made on the gas obtained from sperm oil, and he showed that in illuminating power it was the only gas which could compete with olefiant gas. Soon after that Messrs. J. and P. Taylor contrived an apparatus for procuring the gas on a large scale. Their apparatus consisted of a furnace in which there was placed a twisted iron tube, containing fragments of coke. The object of this arrangement was to increase as much as possible the extent of the heating and decomposing surface. When the tube was red-hot, oil was suffered to run into it in a small and continuous stream. In this way the oil was decomposed and resolved into inflammable vapour which escaped, and a fine spongy charcoal which remained behind. The evolved gases were merely washed with water, and then collected in a gasometer. By this process it was found that a gallon of whale-oil yielded about 90 cubic feet of gas, that had a specific gravity of 900, and was about twice as rich in illuminating principles as the best description of coal-gas. Other patentees, as Mr. English, Mr. Booth, and one or two more, followed in the same course, and endeavoured to perfect the process so as to work it on an economical scale; but, notwithstanding that every means were taken to accomplish this, and that the very commonest oils were used for the production of the gas, it was found that it could not at all compete with the cheaper gas obtained from coal: and so the process was abandoned.

Of late, however, an attempt has been made to revive it by a company which has adopted the name of the Vegetable Gas Company; but, as of old, the attempt has not been successful. Nevertheless, it may be said that where coal-gas is very dear, or not to be obtained at all, or where, for sanitary or other purposes, an unusually pure gas is required, then the process of making oil-gas may be practised with advantage. To meet such cases, a small apparatus has been contrived by Mr. Skelton, and a somewhat similar one is sold by Messrs. Burgess and Key of Little Britain. The latter consists of a small cylinder B (Fig. 45), fitted into a furnace C, so as to be made red-hot. A reservoir I, containing oil, or refuse fat, is suspended to the chimney of the furnace G, and when the fat is perfectly liquid it is allowed to drip from a small tap into a syphon pipe E, whence it runs into the red-hot cylinder and is decomposed. The evolved gases escape by the tube F, and are conveyed by J into a purifier D, which contains water; the delivery tube M dips an inch or so under water in order that the gas may be washed and cooled. The tube K L transmits the gas from the purifier into the gasometer A. The gas which is produced in this manner is of high illuminating power; and it appears from the statements made by the venders of the apparatus, that a pound of kitchen-stuff yields from 10 to 11 cubic feet of gas. Now a pound of this material is 7000 grains; and as the gas produced weighs only about 5000 grains, there is a manifest loss of nearly one-third. This occurs in the form of charcoal, which remains in the retort; and hence the necessity for a frequent cleaning out of this part of the apparatus. Dr. Fyfe states that the loss in his experiments was much greater—that it amounted to nearly one-half of the fat used; and the same remark is also made by Mr. Wright, who has reported upon the comparative economy of the vegetable-gas scheme. The latter gentleman states that for a gallon of 9 lbs. the waste amounts to 2 lbs. 10 oz.

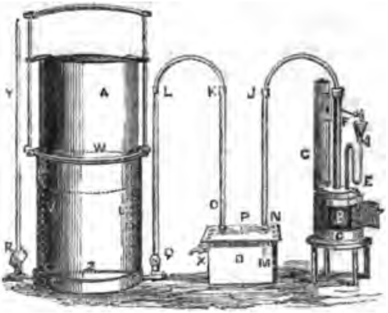

Fig. 45.

The gas which is produced from oil is very heavy; in fact, its specific gravity ranges between 700 and 900. It contains from 30 to 40 per cent. of rich hydrocarbons, which are condensed by chlorine and bromine: of these about 20 per cent. are absorbed by fuming sulphuric acid; 100 volumes of the gas require about 260 volumes of oxygen for their consumption, and they yield 158 volumes of carbonic acid. The durability of the gas, with Dr. Fyfe's four-inch flame from a jet the thirty-third of an inch in diameter, is 68′ 20″; consequently, its value is ten times as great as that of his standard of gas from ordinary Newcastle coal. As might be expected, the illuminating power of such gas is very high: indeed, Mr. Wright has found that it is about four times as great as that of common gas. He states that, with a consumption of one foot and a quarter per hour, it gives the light of twelve sperm candles, each burning at the rate of 120 grains per hour. Our own experiments, however, are not so satisfactory: they are recorded in the following table:—

Burner used.	Consumption per hour.	Illuminating power in sperm candles of 120 grs. per hour.
Small fish-tail	1·50	8
Leslie's Argand	2·25	11
Common Argand, 15 holes	3·50	14
Fine Argand, 70 holes	2·75	12
Winfield Argand	3·50	15

The advantages of this gas are, its freedom from smell; its not containing any sulphur compound; its not producing so much heat as ordinary gas for an equal amount of light; and its easy production in an apparatus which does not occupy much room. Its only disadvantage is its cost; for a shilling's worth of kitchen-stuff will only produce about 40 cubic feet of gas, which will not go farther than six or eight pennyworth of coal-gas.

Portable Gas.—When oil-gas is compressed with a power of from fifteen to twenty atmospheres, it is forced into a very small bulk; and the vessels containing it may be moved about, and placed in any situation where a light is required. A company was formed some years ago for carrying out this object; and they had the gas condensed into globes and cylinders which were placed in vases, columns, and other ornamental devices, so as to be completely hidden from view. Burners were fixed to the apparatus, and the gas was let out by means of a stop-cock of a peculiar construction. In the act of compressing the gas, about one-fifth of its volume underwent condensation into an oily liquid; indeed, a thousand cubic feet of good oil-gas yielded about one gallon of it. This was made the subject of investigation by Professor Faraday. It was a thin oily fluid, lighter than water, sometimes transparent and colourless, at others opalescent, having a red tint by transmitted light, and a green by reflected. Its specific gravity was ·821. This fluid Mr. Faraday found to be a mixture of various hydrocarbons of different degrees of volatility; and taking advantage of this circumstance, he was enabled to separate them. The great bulk of the liquid distilled at a temperature of from 176° to 190°; but a portion also came over at as low a temperature as 98°, and another portion required a heat of about 200° to volatilize it. These liquids consisted of carbon and hydrogen in various proportions. The most volatile was composed of equal atomic parts of carbon and hydrogen (C^4H^4), and a part of the intermediate portion consisted of two of carbon to one of hydrogen (C^6H^3). The others were not sufficiently examined to determine their exact composition, although there was every reason for believing that they were composed, like the first, of equal atomic particles.

M. Couerbe has also examined the liquor which is produced by the compression of resin-gas, and his results are quite as interesting as those of Professor Faraday. He finds that the liquid contains six different fluid hydrocarbons; five of which consist of four atoms of hydrogen and a number of carbon that rises in arithmetical progression from four to eight. The sixth is a compound of twenty-eight atoms of carbon and twenty-two of hydrogen.

Resin Gas.—When it was found that oil could not be profitably used for the manufacture of gas, attention was naturally directed to other and cheaper gas-producing substances. Resin was therefore selected; but it was noticed that when this body was decomposed in the apparatus commonly employed for the generation of oil-gas, it produced a quantity of thick bituminous matter which choked the exit-pipe. This, at first, was regarded as an insurmountable difficulty; but it was overcome by the late Professor Daniell, who contrived an arrangement whereby the gas was delivered from the bottom of the retort by means of a descending pipe. His patent was taken out for this contrivance about thirty years ago, and Messrs. Taylor and Martineau were the first to put it into operation on a large scale. The retort was set in the furnace in the usual manner, and it was charged with coke in order to increase the heating-surface. Across the farther end of the retort there was a diaphragm, or septum, which was open at the top; and beyond this was the communication with the down-going delivery-pipe. The diaphragm served to prevent any of the coke from falling into the exit-tube. The resin was dissolved, or rather liquefied, by the aid of heat, in a small quantity of oil of turpentine, or of the volatile oil produced by the decomposition of the resin in a former process. The proportions were about twenty pounds of resin to a gallon of oil. This mixture was kept hot and fluid, in a reservoir placed over the fire above the retort; and when the contents of the latter were red-hot, it was allowed to run through a syphon tube, and to drop upon the incandescent coke at the nearest end of the retort. The vapours which were thus produced passed along the whole length of the retort, and were completely decomposed before they escaped over the diaphragm into the descending-pipe. A part of these vapours were liquefied by the cold of the condenser, and they appeared as a limpid volatile oil; the other portion passed on as gas; and, after having been purified by washing with lime-water, it was collected in the gasometer. This process of Daniell's was considered to be very complete, though it has been modified in certain particulars by subsequent patentees: thus, Mr. Richardson has proposed that the resin should be mixed with saw-dust and some alkali, as lime, potash, or soda; and that it should be put into the retort in thin sheet-iron vessels of a cylindrical form. Here the first distillation takes place, and the volatile products are conveyed into other vessels, or retorts, charged with coke, lime, or broken bricks, kept at a red heat. By this means it is thought that more gas, and less volatile oil, will be obtained. Mr. Webster generates the gas in another way. He passes the vapour of coal-naphtha over a bed of heated coke, and thence over a quantity of melted resin. The volatile matters so obtained are made to traverse another vessel filled with incandescent coke, and here they undergo decomposition.

A pound of resin will yield about ten cubic feet of gas, or, more correctly speaking, a hundredweight of resin will furnish from 1000 to 1200 cubic feet of gas, and about three gallons of oil. The gas has a specific gravity of from 660 to 850; and its illuminating power is only a little inferior to that of oil-gas. When it is imperfectly made, it does not contain more than eight or ten per cent. of condensable hydrocarbons; and such a gas was found by Dr. Fyfe to have a durability of fifty-three minutes and twenty seconds—its value therefore is about the same as that of gas from Wigan cannel. As in the case of oil-gas, this illuminating agent does not contain a particle of any sulphur impurity.

The volatile oil which is produced during the manufacture of gas from resin is worth about 7*d.* per gallon; and it may be used for dissolving resin, caoutchouc, &c. When it is distilled, it yields about one-seventh of its bulk of a more volatile oil, which is worth 2*s.* 3*d.* a gallon—the residue being of the valve of 5*d.* a gallon.

Although the production of gas from resin is not practised in this country, in consequence of the more economical source of it from coals, yet we believe that in many parts of America, where resin or crude turpentine is cheap and abundant, the process is still worked with advantage.

Hydrocarbon Gas.—This is the name given to the mixed gases which are generated from water, and certain substances that are rich in hydrocarbons, as tar, resin, fats, oils, and the better kinds of cannel coal.

Although this description of gas has only very recently been made on the large scale, yet the principles of its manufacture were known and appreciated many years ago. As far back as the year 1830, Mr. Donovan took out a patent for the generation of gas from steam, by passing it over red-hot coke or charcoal; and he subsequently naphthalized it at the burner by means of turpentine or coal-tar. Since that time many improvements have been made in the process; and we may refer to the names of Manby, Val-Marino, Radley, Lowe, White, Croll, Webster, Barlow and Gore, in proof of the number of persons who have taken out patents in this country for the generation and naphthalization of water-gas. In every case the water, or rather the steam, is decomposed by passing it over red-hot coke or charcoal; and it is subsequently naphthalized by mixing it with rich hydrocarbons.

The details of the process vary somewhat with the nature of the materials used. When fat or resin is employed for the production of the gas, the process, as described by Mr. White in his patent, is as follows:—Two retorts, about seven feet long and nine inches in diameter, are set vertically in a furnace so that they may be heated to full redness, or even to an incipient white heat. A flue passes through the centre of each of the retorts, in order that the contents may be thoroughly heated. They are packed full of coke, charcoal, or anthracite, and a few scraps of iron. When the retorts are red-hot, water is allowed to flow through a syphon upon the top of the ignited mass. The steam which is thus generated passes down through the red-hot coke, and is decomposed into hydrogen and carbonic oxide, with more or less of carbonic acid. The gases and vapours thus produced, escape from the bottom of the retorts into two other retorts placed horizontally in the same furnace. These are about six feet long, and are divided into two or more compartments by longitudinal septa which reach nearly to the end. The compartments are filled with coke, chain or coils of iron wire, so as to increase the surface; and into the first of these, tar, fat, or resin is allowed to flow, so as to undergo decomposition. The evolved gases are rapidly carried off and mixed with the gaseous products of the first retort; and after they have passed through a condenser and a lime purifier, they are received into the gasometer. In working the process, the supply of the materials should be so managed, that the gaseous mixture should consist of about four parts of water to six of the other. When resin is used, the proportions of the various materials are one hundredweight of resin, seven and a quarter gallons of resin-oil, fifteen pints of water, a sixth of a bushel of charcoal, and a few ounces of scrap iron. These produce from 1500 to 1600 cubic feet of gas, and about three gallons of oil over and above the quantity originally used. Dr. Frankland has entered into a very detailed examination of this process; and it appears from his report, that a hundredweight of resin, with from thirty to forty pints of water, will yield from 1500 to 1900 cubic feet of gas, and from two to four gallons of oil. The temperature at which the best results are obtained is that of dull redness; for if the heat be carried much above this point, the richer gases are decomposed and evolved into several gases of low illuminating powers. He found that two distinct changes were effected in the water retorts. In one case the steam was decomposed by the red-hot charcoal, and resolved into equal volumes of hydrogen and carbonic *oxide;* in the other, it was converted into two volumes of hydrogen, and one of carbonic *acid.* These mixed gases, together with some undecomposed steam, pass into the resin retort, where they mix with the vapours of the decomposing resin, and pass twice along the length of the red-hot retort. Here the steam is again subjected to decomposition by the agency of the fuliginous matter evolved from the resin. This change is a very important one, for it prevents the accumulation of carbon in the exit-pipe of the retort. If the gas be examined at this stage of its manufacture, it will be found to contain a very large proportion of carbonic acid; and one of the greatest difficulties in the subsequent management of the gas is the removal of this impurity. Ordinary wet lime will only remove a portion of it; and hence Dr. Frankland has recommended the use of caustic soda, which may be produced by the admixture of carbonate of soda with cream of lime.

The gas which is thus produced has a specific gravity of from 600 to 660. It contains from seven to eight per cent. of condensable hydrocarbons; and its illuminating power is about the same as that of ordinary cannel gas. Its composition, both before and after the removal of carbonic acid, is as follows:—

	Ordinary gas.	Pure gas.
Condensable hydrocarbons	7·41	8·13
Light carburetted hydrogen	26·50	29·71
Hydrogen	40·27	43·38
Carbonic oxide	18·55	18·78
Carbonic acid	7·27	0·00
	100·00	100·00

According to Dr. Frankland's report, hydrocarbon gas from steam and resin may be manufactured at from 9½*d.* to 1*s.* 1½*d.* per 1000 cubic feet. This is irrespective of the cost of the apparatus, or of the charge for wear and tear.

When the gas is made from rich cannel coal, the arrangement of the apparatus is a little different from the preceding. Indeed, the patentee now adopts the following as the general plan of his operations:—

Both the retorts are placed horizontally, and they are divided into two compartments by means of a longitudinal septum that reaches nearly to the end of each. One or more of these, called the water-retorts, are charged with coke; and after being raised to a high temperature, water is allowed to trinkle through a syphon pipe upon the red-hot coke at the outer end of the upper compartment. The steam which is thus generated passes through the ignited contents of the upper compartment, and thence descending behind the septum, it comes forward through the lower. By this means it is exposed to a large surface of red-hot charcoal, and is in great part decomposed and resolved into hydrogen, carbonic oxide, and a little carbonic acid, all of which enter the lower compartment of another retort, which is charged with cannel coal. Here they mix with the various hydrocarbons that are evolved from the coal; and after traversing the retort from one end to the other and back again, they pass into the condenser and wet-lime purifier, and thence into the gasometer. Dr. Frankland states, that by this mode of working, all the carbonic acid which is generated in the water-retort is decomposed by the fuliginous matter of the coal, and converted into twice its bulk of carbonic oxide. It is thought, also, that the water-gases exert a conservative influence on the rich hydrocarbons which are evolved from the coal; and that by sweeping them away as fast as they are produced, and so protecting them from the destructive agency of heat, a much larger quantity of illuminating matter is obtained.

Dr. Frankland has examined the value of this process, as applied to different varieties of cannel coal. He worked with one hundredweight of each of the following coals, and he obtained the following amounts of mixed hydrocarbon gases. The coals were placed in each of the compartments of the second retort, and they were distilled at a low red-heat. The water-gas was obtained in the usual manner:—

Name of coal.	Yield per ton.	Illuminating power of the gas in sperm candles.
Wigan (Ince Hall)	16,120	20·0
Ditto (Balcarres)	15,500	19·1
Newcastle cannel	15,020	18·8
Methyl	26,400	21·0
Lesmahago	29,180	28·7
Boghead	51,720	17·9

The illuminating power was tested in the usual way with a No. 4 fish-tail burner, consuming five cubic feet per hour, at a pressure of half-an-inch of water; and the candle was a sperm candle, calculated to the amount of 120 grains per hour. According to Dr. Fyfe's mode of estimating the value of the gas, an average sample has a durability of 43 minutes and 20 seconds, and its amount of condensation by chlorine was 11·44 per cent.; so that its quality was about 2¼ that of ordinary gas from Newcastle coal.

Mr. Clegg speaks in the most enthusiastic terms of the value of this process. He says that a ton of Wigan coal yields, under ordinary circumstances, about 10,000 cubic feet of twenty-candle gas; while with the hydrocarbon process it furnishes 16,000 cubic feet of gas of the same quality, and 26,000 cubic feet of twelve-candle gas. A ton of Lesmahago cannel produces in the usual way 10,500 cubic feet of forty-candle gas, but with the hydrocarbon process it will yield 36,000 cubic feet of twenty-candle gas, or 58,000 cubic feet of twelve-candle power; and a ton of Boghead, which generally furnishes about 13,500 cubic feet of forty-candle gas, will by this process give as much as 52,000 cubic feet of twenty-candle gas, or 75,000 of twelve-candle. From which it is manifest that, although there is a comparative reduction of the illuminating power in consequence of the diluting power of the water-gas, yet, on the whole, there is a considerable increase in the amount of illuminating matter. This increase varies from 50 to 100 per cent.; and it is, no doubt, due to the property which water-gas has of suspending the volatile hydrocarbons which are generally condensed in the tar.

Mr. Clegg states that the cost of working the process is not very considerable, for gas of twenty-candle power may be obtained from Wigan coal at the rate of 1*s.* 3¼*d.* per 1000, from Lesmahago at 11¾*d.*, and from Boghead at 11*d.*: besides which, the gas is remarkably free from every kind of sulphur compound. The conclusions at which Dr. Frankland has arrived, after having made a very careful examination of Mr. White's process, are the following:—

1st. That it greatly increases the produce of gas from a given weight of coal, the increase being from 46 to 290 per cent., according to the nature of the material operated upon.

2nd. That it greatly increases the total amount of illuminating power, the increase being from 12 to 108 per cent.

3rd. That it diminishes the quantity of tar formed, by converting it into gases of high illuminating power.

4th. That it affords a means of reducing the illuminating power of gases which could not be profitably burnt alone: and

5th. It may be easily applied to any of the apparatus or modes of working now in use.

In opposition to these conclusions must be placed the results obtained by Messrs. Brande and Cooper, who found that little or no advantage was gained by the process; and Dr. Fyfe, who is much opposed to the whole scheme, states that, when all things are considered, it is a process which ought at once to be abandoned. Mr. Barlow has, however, recently examined the merits of the process; and he believes that, with some few alterations in the way of working, it may be profitably carried out. His suggestion is to collect the water-gas in separate gasometers, and to convey it from them, instead of from the retorts, into the compartments where the coal is distilling. By this means he avoids the injurious action of undecomposed steam, and he effects the decomposition of carbonic acid, which is at present so serious an impurity.

Water Gas alone.—Several patents have been taken out, at various times, for the production of gas from water; and the employment of such gas either alone, as when it is wanted for heating purposes, or in combination with the vapours of naphtha. Donovan's patent, of 1830, we have already alluded to. M. Floret has contrived a power for decomposing steam, by means of coke heated to a high temperature in an atmosphere of oxygen. Mr. Paine, of America, says he decomposes water by the aid of electro-magnets; Mr. Adams, of Boston, effects it by the force of a galvanic battery; and Mr. Shepard assists the action by using a salt of ammonia, or a vegetable acid, as oxalic. In Mr. Gillard's process steam is decomposed by passing it over incandescent charcoal, in such a manner as to form hydrogen and carbonic acid; the latter being absorbed in the usual way by means of caustic lime. All these patents, however, are but so many examples of fruitless speculation; and they may be pointed at as illustrations of most unsound chemical knowledge, combined with the very worst kind of practical experience.

As the hydrogen and carbonic oxide produced by either of these processes does not possess the smallest amount of illuminating power, it must be brought up to the required standard, either by passing it through a volatile hydrocarbon, or by burning it in such a way as to make a solid incombustible body white hot. Mr. Gillard adopts the latter contrivance; and his plan is to consume the gas from an Argand burner, over which there is suspended a rosette of platinum wire. The wire becomes intensely heated; and, when the gas is burning at the rate of six and a half cubic feet an hour, the light emitted is about equal to five composite candles, or to that of a fish-tail consuming three feet of ordinary gas per hour.

Wood Gas.—When wood is subjected to distillation in closed iron vessels it evolves a large quantity of inflammable vapour, some of which condenses into a liquid form, while the rest passes off as combustible gas. The liquid consists of water, pyroligneous acid, naphtha, and a complex heavy tar; and the gas is composed of hydrogen, carbonic oxide, carbonic acid, light carburetted hydrogen, and a variable proportion of olefiant gas. When these are consumed in the ordinary way they do not produce much light; but if they are passed through a volatile hydrocarbon, they may be brought up to any degree of illuminating power. It is possible, also, that by certain modifications of the process whereby they are obtained, a sufficient amount of rich hydrocarbons may be generated, to do away with the necessity for subsequent naphthalization. Mr. Hills proposes to mix the gases which are obtained during the manufacture of crude pyroligneous acid, with those which result from the destructive distillation of coal-tar; and Mr. Lowe has taken out a patent for the use of tar, oil, resin, or cannel coal, as a means of giving illuminating power to the gases evolved from sawdust, spent bark, or peat. Other patentees have suggested that the sawdust and tar should be mixed together before they are distilled; but it does not appear that any of these schemes have been successful in practice, or have been able to compete with the more economical mode of obtaining gas from coal. On the Continent, however, where wood is very abundant, and coal scarce, it is frequently more profitable to make gas from the former than from the latter. At Basle, for example, and some other towns of Switzerland, Norway, and Sweden, the process of distilling gas from wood is practised on a very large scale. We are told that the old city of Heilbrown has recently been lighted up with wood-gas; the manufacture of which is under the management of M. Schäufelen, who produces a gas of very good illuminating power. It is said that a fish-tail burner consuming four and a half cubic feet per hour, gives the light of thirteen wax candles; and that one of five cubic feet an hour, produces the light of sixteen candles; while an Argand burner, on Dumas' construction, consuming the same amount of gas, evolves the light of twenty candles. If this be so, it is evident that wood-gas can be obtained of a quality superior to that of ordinary coal-gas.

Peat Gas.—This is nearly of the same composition as the gas evolved from wood; and the collateral products are nearly of the same description and value. Many chemists have, at different times, devoted their attention to this subject; but it is only very recently that precise information has been obtained concerning it. Sir Robert Kane in Ireland, and Dr. Letheby in England, have each reported on the quality of the products generated during the destructive distillation of peat; and from their statements it appears, that 100 parts of peat will furnish from 19 to 40 of charcoal, from 2 to 5 of tar, from 11 to 38 of aqueous matters, and from 25 to 58 of gas. The charcoal is very valuable as a decolorizer and disinfectant; the tar is rich in paraffine and creosote; the watery fluids contain ammonia, acetic acid, and wood-naphtha; and the gases consist of hydrogen, carbonic oxide, carbonic acid, and various hydrocarbons. 1000 parts of peat will yield, on an average, 2·7 of ammonia (equal to 10·4 sulphate), 1·9 acetic acid, 1·4 wood-naphtha, 7·9 volatile oils, 5·5 fixed oils, and 1·4 paraffine. From Dr. Letheby's experiments it appears that a ton of peat will furnish about 13,000 cubic feet of gas, the illuminating power of which is equal to seven standard candles, when the gas is burnt from an Argand that consumes five cubic feet per hour; but the intensity of the light may be brought up to any degree by the usual process of naphthalization. As peat is very abundant, its products valuable, and its gas entirely free from sulphur, it is very probable that it may be used with great advantage as a source of inflammable gas: in fact, a patent has recently been taken out by Mr. Hansor of London, for the manufacture of an illuminating gas from a mixture of 12 parts of peat, 12 of resin, 8 of coal-tar, and 16 of oil. This is effected by distilling the mixture from perforated iron boxes, placed in a furnace heated to a cherry-red; the condensable vapours so produced are then passed through another furnace divided by diaphragms, and heated to a bright red. By this means they are decomposed, and rendered permanently gaseous. The gas so obtained, after having been purified by means of lime, has a density of ·626, and its illuminating power is a little higher than that of common cannel-gas, or it is about twice as great as that of ordinary coal-gas. A fish-tail burner consuming 2·5 cubic feet per hour gives the light of 9·2 standard sperm candles, and an Argand consuming 3·5 feet gives the light of 15·5 candles. One of the great advantages of the gas is its perfect freedom from every kind of sulphur impurity. A company has been formed, under the name of Hansor's Olefiant Gas Company, for carrying the patent into full operation.

Gas from Wine Lees and Grape Skins.—These substances are said to produce a very good gas. One pound weight of either of the materials will furnish seven cubic feet of gas of more than ordinary quality. This fact was demonstrated in the year 1849 by M. Levenair of Bordeaux, and Dr. Berhardt of Paris, in one of their public lectures before the Faculty of Sciences. If the results be uniform, the process affords an easy means of obtaining gas and other valuable products, from a material that has hitherto been used only as a manure; besides which, the residue of the distillation is just as valuable to the wine-grower as the lees themselves.

Gas from Coal Tar.—This liquid has again and again been made the subject of experiment, in the hope that the rich hydrocarbons which it contains might be converted into permanent gases of high illuminating power; but, hitherto, all attempts at effecting this desirable result have signally failed. In the year 1820, Mr. Lowe contrived an apparatus for decomposing coal-tar, and resolving it into permanent gases. It consisted of a furnace with five retorts, three of which were placed below, and two above. These were charged in the ordinary way with coal; and when the carbonization had gone on for three hours, the tar was allowed to flow through a syphon-pipe into the back part of the upper retorts,—these being the hottest. Here the tar was converted into vapour, and it passed over the incandescent surface of the charge to the front of the retort, where it escaped through the exit-pipe, to the hydraulic main. According to Mr. Lowe, he was enabled to produce, by this arrangement, a maximum quantity of gas of high illuminating power; but, although the process was worked upon a very large scale under the immediate superintendence of the patentee, it did not succeed, and it was soon abandoned. Since that time a number of patents have been taken out for a like purpose; but none have been successful. In some cases the tar has been mixed with small coals; in others with peat; in others with sawdust; and very recently Mr. Way has proposed the use of a porous stone which he saturates with tar. Some have distilled the material at a low heat, others at a moderate temperature, and others at a very high one: so that every species of ingenuity has been exhausted in endeavouring to convert this rich inflammable fluid into a permanent gas.

Other organic substances have been resorted to as a source of gas. M. De Cavaillon has proposed a mixture of bones, suet, oleaginous seeds, spent bark, sawdust, molasses, and small coal. Mr. Booth has claimed the use of resinous woods and oily seeds. Mr. Witty has patented a mixture of vegetable oils, and refuse vegetable matters, such as spent hops, dry peat, or dry sawdust, which he presses into blocks, and distills in earthenware retorts; and then, again, it may be said that Mr. Lowe has obtained a patent for naphthalizing gases from any source, by passing them through a vessel containing coal-naphtha—a process that was suggested many years ago by Dr. Henry of Manchester. Lastly, Mr. Archibald has gone so far as to naphthalize atmospheric air in a somewhat similar way. He first saturates the air with moisture, and then conveys it through benzole, which is the most volatile of the coal-naphthas. He also passes the air through a mixture of one part of benzole, two of alcohol or wood-spirit, and one and a half of water. By this means the air acquires inflammability, and may be burnt from an ordinary gas jet: it may even be stored in gasometers, and distributed in the same way as coal-gas. If the air is not saturated with moisture, so much cold is produced by the volatilization of the benzole as to stop the process of naphthalization; and hence the necessity for adding water to the hydrocarbons.

ON THE APPARATUS REQUIRED FOR THE CONSUMPTION OF GAS.

The Gasmeter.—When gas was first used by the public, it was sold at an annual rent, at so much per burner; but it soon became apparent that this was not a fair mode of dealing with the article, and hence the ingenuity of the mechanic was taxed to contrive a means whereby the gas might be accurately measured. This was accomplished by Mr. Clegg, who in the year 1815 constructed the first meter. In the following year he improved it so far as to obtain a patent for it. At first Mr. Clegg attempted to register the gas by means of two small gasometers, which rose and fell alternately, one receiving the gas while the other was delivering it. But this plan was not successful, and it was, therefore, abandoned for another which constitutes the basis of all the wet-meters that have been contrived since Mr. Clegg's time. It consisted of a drum, which revolved in a chamber half-filled with water. The drum was divided into two compartments, one of which received the gas while the other delivered it. The gas entered through the hollow axis of the instrument; and as the drum revolved and submersed the compartment, the gas was forced through a lateral opening into the outer chamber, and thence to the burners. By means of valvular contrivances, two of which were closed by water and two by springs, the gas was made to flow only in one direction; but as the spring-valves were easily thrown out of order, and the water-valves were of a clumsy form, the instrument was susceptible of very great improvement. Mr. Malam, therefore, in 1819 reconstructed the apparatus. He divided the drum into five compartments—one of which was central, and the others around it (Fig. 46). As in Mr. Clegg's instrument, the gas entered the apparatus through the axis of the drum; but in order that there should be no friction or impediment to its movement, he did away with the stuffing-box in which it worked, and brought the central tube or axis, by means of a rectangular bend, up above the level of the water in the central chamber *d*. He also put aside the clumsy water-valves and the too delicate spring-valves of Clegg's instrument, and adopted a simple contrivance whereby the delivery apertures were made to act of themselves by simply rising above the level of the water. These apertures were in the form of slits, which communicated first between the central chamber and the circumferential ones, and then between the latter and the outer case. On entering the central compartment, the gas escapes through whichever of the first set of slits happens to be above the level of the water. In the figure it is passing from *d* into *a*. This gives a buoyancy to that chamber; and as it rises or floats, it turns the drum round from right to left, causing the gas which is in the upper and descending compartments to escape through their outer slits into the outer chamber, and thence to the burner. It will be noticed that, as the drum revolves, the entrance-slits between the middle and outer chambers are successively carried under the water, and that as soon as this happens, the exit-slits in the circumference of the drum are each in their turn brought out of it. This is shown in the figure as about to occur with compartment *c*, whose entrance-slit is just dipping under the water, while the exit-slit is rising out of it. Since the time of Mr. Malam, other improvements have been effected in the details of this meter; by means of which the revolution of the drum has been made steadier, the amount of friction lessened, and the water kept at one uniform level. Among the names of those who have devoted attention to the subject, are Crosley, Wright, Evans, Hulet, Smith, Paddon and Ford; all of whom have, in some particular or another, perfected the instrument.

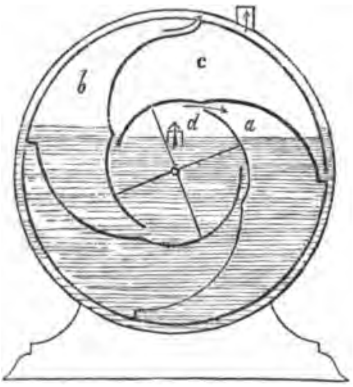

Fig. 46.

Figs. 47 and 48 represent a meter of modern construction, with most of the improvements adopted. The gas passes by the inlet-pipe *a* into the chamber *b*, whence there is a communication by means of a flat valve with the compartment *c*; from this it passes through the bent pipe, forming the axle of the drum, into the compartment *d*, and thence, in the manner already described in Malam's meter, it gets into one or other of the four compartments, and so escapes by an exit-slit into the space formed by the surrounding case. *f* is a ball which floats on the water and keeps the flat valve open. If the water gets below its proper level, the ball falls; and by bringing down the valve, shuts off the gas. *g* is a tube for passing water into the cistern, and *i* is a waste cistern for receiving the water when it gets above the proper level and flows over. *h* is a syphon-tube for drawing off the water which has been added in excess. By a train of wheelwork, the revolutions of the drum are communicated to the hands on the dial-plate; and thus the quantity of gas consumed is registered.

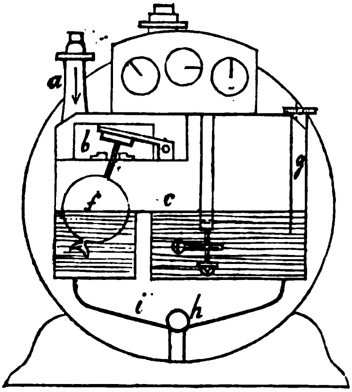

Fig. 47.

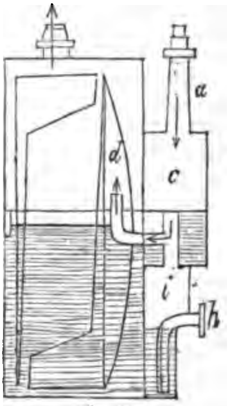

Fig. 48.

There are two objections to the wet meter, which are insurmountable. These are, that the instrument registers the vapour of water as well as gas; and, secondly, that it is very liable to stop, at an unexpected moment, by the deficiency of water and the sinking of the float. When a meter is placed in a warm situation, the quantity of aqueous vapour that is registered by the instrument, and set down as gas, is very considerable; and if it should so happen that the gas, after passing the meter, has to traverse a cold locality, the aqueous vapour will be recondensed as water, and will cause a flickering of the flame, or even a total occlusion of the pipe.

At one time it was possible for the gas companies to derive an advantage from the overfilling of the water-cistern, whereby the capacity of each measuring chamber was somewhat diminished; and thus a revolution of the drum did not record a proper quantity of gas. It was also possible for the company to be defrauded by a deficiency in the amount of water; but now both of these objections are guarded against by the waste-tube and cistern on the one hand, and by the float-valve on the other.

It will be seen, by an examination of the meter represented in Fig. 46, that, by tilting the meter a little on one side, the gas will pass through the slits of the uppermost chamber without turning the drum at all, and frauds are sometimes committed in this manner; but the experiment is a very dangerous one, and is not likely to be practised by any but the most determined rogue.

The *dry-meter* is a more complicated apparatus, though it consists in all cases of a chamber, or set of chambers, with flexible leather sides. The action is very similar to that of a pair of easy-going bellows; and the movement is communicated to levers and rack-work, which not only register the amount of gas that passes, but, by a set of sliding valves like those of a steam-engine, they also cut off the supply of gas from one chamber, and turn it on into another.

The first dry-meter was patented by Mr. Malam in 1820: it consisted of a set of six bellows placed in a radiating direction around a common centre, the whole being inclosed in an air-tight chamber. These bellows worked successively one after the other, and they communicated their motion to a set of wheels, which served to register the quantity of the gas delivered. This machine was, however, not perfect—it had many radical faults; and hence it did not come into general use. Next after this was the instrument constructed by the Dry-Meter Company. The measuring chamber was formed of leather, which was found to be liable to many objections; for if the meter was used constantly, the leather expanded under the influence of the gas, and so it recorded against the interest of the company; whereas, if it were not used so constantly, it underwent contraction, and then it registered against the consumer: besides which, the valve moved so suddenly from one side to the other as to produce an unsteady flame, and hence the meter was not much patronized. Sullivan's meter, which followed upon this, was open to the same objections; for it consisted of two loose leather diaphragms and a rotatory valve. In 1833, an American, by the name of Berry, patented an instrument which was invented by a person named Bojardin. The meter was a hollow chamber, which had a moveable diaphragm or partition that divided it into two compartments, and, by means of sliding valves, the gas was alternately let in or out of them. In 1836, Bojardin invented a still better machine; and he is looked upon as the originator of the present form of dry-meter. Since that time, Mr. Defries, Mr. Edge, and Mr. Croll have improved the instrument, and brought it into its present condition. Mr. Defries' meter contains three measuring chambers, which are separated from each other by a flexible partition formed of leather, and partially protected from the action of the gas by four triangular metal plates, which almost cover the diaphragm. This flexible partition is raised or depressed by the gas, so as to form a pyramid or a flat surface; and the rise and fall of the partition is communicated to the wheelwork of the apparatus; but, as in all cases where leather enters into the construction of the measuring chamber, the instrument is very liable to register incorrectly. The meter which is manufactured by Messrs. Croll and Glover is said to be free from this objection: its construction will, perhaps, be understood from the following account, taken from Mr. Croll's paper, which was read before the Society of Civil Engineers in 1845. If we imagine a steam-engine measuring its steam by the movements of the piston, we shall have some idea of the principle of the instrument. The steam enters the cylinder over the piston, and forces it down through a certain space; the supply is then cut off, and the action is reversed. Now, suppose the piston to be of a given area, and the distance through which it moves at every stroke to be constant, it can readily be conceived how the actual quantity of steam employed could be indicated and calculated. The meter in question bears a strong resemblance to a double engine: it consists of a cylinder divided by a plate in the centre into two separate cylindrical compartments, which are closed at the opposite ends by metal discs; these discs serve the purpose of pistons, and they are kept in their places by a kind of universal joint adapted to each. The space through which the discs move, and consequently the means of measurement, is governed by metal arms and rods; which space, when once adjusted, cannot vary. To avoid the friction occasioned by a piston working in a cylinder, a band of leather is attached so as to act as a hinge. This folds with the motion of the discs, but it is not in any way concerned in measuring the gas; so that if it were to contract or expand, the registration of the proper quantity of gas would not be affected; for such a change would only decrease or increase the capacity of the hinge, leaving the disc still at liberty to move through the required space. The leather is also attached in such a manner as to avoid folds, and thus to render it more durable.

Gas-Burners.—Scarcely anything connected with the subject of gas illumination has commanded more attention than the means whereby gas may be burnt to the best advantage; and although the greatest ingenuity has been displayed in the construction of many of the burners which have at different times been invented, yet none of them possess that universal applicability for which they have in most cases been so highly vaunted. The reason of this is obvious: different kinds of gas require different forms of burners, in order to effect perfect combustion. As a rule, it may be stated that the rich cannel gases are best consumed from burners with very fine apertures: while the poorer gases—namely, those which contain less than five or six per cent. of condensable hydrocarbons—are burnt with most advantage from larger apertures. Again, in the former case, provision should be made for a large supply of atmospheric air, as by spreading out the flame by means of an internal button, or by using tall glasses; whereas in the latter case, the very opposite condition should be observed. It is manifest, therefore, that no single burner can be constructed so as to secure both of these requirements; and, consequently, that any burner which is well suited for one kind of gas, is altogether unfit for the other.

Another point of importance to which we may refer in speaking of this subject, is the following:—that when several jets issue from the same burner, and blend together or coalesce, the light is always improved; for it is the property of one jet to assist another by exalting its temperature; and thus a greater heat and a brighter flame are the result of the union,—more light being given out than is the sum of the individual jets. It is on this account that the Argand burner, the fish-tail, the Gaumont, and the Gardner, have obtained preference over many other forms of burners.

Lastly, it may be stated, that in whatever way gas is consumed, the maximum effect, as regards its illuminating power, is always produced by burning the gas just short of its smoking point: for if it be burnt with too much air, the particles of carbon are consumed; and we thus obtain less and less light, until the flame becomes of a pale blue colour. On the other hand, if it be burnt with too small a supply of atmospheric air, the particles of carbon will not be sufficiently consumed, and they will escape as soot,—thereby cooling the flame, and making it of a dingy yellow tint. Our object, therefore, should always be to burn the gas in such a manner that the particles of carbon may be first intensely heated, so as to produce a white light; and then, as they reach the exterior of the flame, they ought to be consumed entirely, so as to avoid the evolution of soot. Of the different varieties of burners now in use, the following are the most important:—

1. *The simple jet* is produced from a burner pierced with a single hole. This mode of consuming gas is not considered to be cleanly or economical; and, except for certain purposes of illumination, as where we wish to produce different kinds of devices, it is rarely employed. Occasionally it is used in the laboratory of the chemist for experiments with the blowpipe, as it is found to give a much hotter and clearer flame with this instrument than any other form of jet. The average consumption of a jet the thirty-third of an inch in diameter, with a flame four inches high, is about one cubic foot per hour. With richer gases the quantity is a little less, and with very poor gases it is somewhat more. As we have already said, Dr. Fyfe prefers a jet of this description for the purpose of estimating the illuminating power of gas; and in a general way it is equal to from one to one and a-half, or two sperm candles.

When it is necessary to produce a greatly diffused light, it may be accomplished by means of one or more rows of single jets. These may be distributed around the cornice or mouldings of a room, and the effect is remarkably pleasant and agreeable, for there is a flood of light without the least glare or shadow. This plan of illumination has been adopted at the Philharmonic Hall at Liverpool, where about 1000 jets are placed upon the cornice around the room; and Mr. King stated in his evidence before Parliament, that the result is highly satisfactory, and that many persons who see it are disposed to ask—"Whence does this light come from? Is it possible that these small jets are producing this body of light?" The same effect is seen in the streets during the nights of general illumination; and it is also witnessed in the Guildhall of London at the time of the Civic fetes. The only objection to it is its great cost and its liability to evolve smoke; but if these were overcome, and our rooms constructed so as to have a row of lights around a panel in the ceiling, there is no doubt that the effect would be much more pleasing than that which results from our present mode of burning gas; besides which, the panel might be so arranged as to convey away the products of combustion, and thus the effect would also be more salutary.

2. *The Cockspur Burner* is a burner with three or more jets radiating off from it and burning separately. The light from such a burner is only equal to the sum of the individual jets; for as they do not coalesce, they cannot in any way assist each other. It is one of the very worst forms of burner that can be employed. A burner with three jets, consuming three cubic feet per hour of ordinary London gas, gave a light of from five to six candles.

3. *The Fish-tail* or *Union Burner* is so named because of the form of its flame, and because of the manner in which it is produced by the union of two jets. It is formed by drilling two holes at an inclination or angle of about 60°. The jets are directed into each other; and as they coalesce, they spread out so as to produce a flat sheet of flame of the form of a fish-tail: by this means the intensity of the light is greatly increased. The holes are drilled large or small, according to the quality of the gas to be employed. In the case of cannel gas, the holes are small; and for common London gas they are rather large. The former are known by the name of Lancashire or Scotch fish-tails, and the latter as London jets. Each sort is numbered 1, 2, 3, or 4, according to the size of the holes; and these numbers are indicated by means of little rings turned on the body of the jet. No. 1 is the smallest. These burners consume from two to four cubic feet of gas per hour; and with cannel gas they give the light of from eight to fourteen candles, and with common gas of from four to ten.

4. *Johnson's Burner* is a fish-tail with four converging holes; and there is an aperture through the centre of the burner for the admission of atmospheric air into the flame. We have no knowledge of the economic value of this burner.

5. *Billow's* or *Gardner's Burner.*—This is a combination of two fish-tail or bat's-wing burners, arranged so as to produce one flat flame (Fig. 49). The flames impinge on each other, and thus increase the illuminating power by about thirty per cent. These burners are usually constructed of two fish-tails; and occasionally, for experimental purposes, they are attached to a hinge-joint, so that the flames may be burnt separately or together. As in the case of the ordinary fish-tails, they are numbered 1, 2, 3 and 4. No. 1 consumes about three cubic feet per hour, and No. 4 about five.

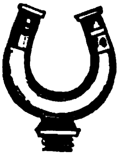

Fig. 49.

6. *The Bat's-wing Burner* is so named on account of the shape of the flame. It is one of the oldest forms of gas-burners; it is constructed with a slit instead of two holes for

the exit of gas; and the flame is broader and not so high as the fish-tail. These burners are easily managed, and on this account they are generally supplied to the public lamps. They burn from three to five cubic feet per hour; and with a consumption of four cubic feet per hour they give the light of about nine sperm candles of standard quality.

7. *The Gaumont Burner* is a bat's-wing burner with two or three slits, instead of one. By means of this contrivance there are two or three flames amalgamated into one; and, as is always the case under these circumstances, the total amount of light is increased. A Gaumont which consumes three cubic feet per hour, gives the light of seven sperm candles.

8. *The Sun Burner* is a cluster of fish-tail burners, usually nine in number, placed around a common axis, and spreading out in a horizontal direction, so as to produce the figure of a flower or the sun. This burner is so constructed, that the products of combustion are carried out of the room by means of a ventilating funnel and tube placed immediately over it; and the air which supplies the flames is made to descend along the ventilating tube, and thus to become very hot before it reaches the burner. By this arrangement there is a great saving of gas. In most cases the sun-burner consists of seven clusters of nine fish-tails each. The burners are supplied with gas by a descending-pipe, which branches to each cluster; and surrounding the whole is a sheet-iron cone, with a tube attached to the top, for carrying off the products of combustion. In this tube there is placed a butterfly-valve, for the purpose of regulating the current of air, so that the draught may not be too great, and the lights may burn in a horizontal direction. Around the cone are placed three other sheet-iron cases, which not only serve for ventilation and for the supply of air to the burners, but also insulate the inner cone, and by their cooling effect, prevent the intense heat of the latter from being communicated to the woodwork of the ceiling. These cylinders are not connected to each other, or to the cone, and, therefore, distinct currents of air pass between each of them; and such is the cooling effect of these currents, that, while the cone is red-hot, the two outside cases are of the same temperature as the atmosphere of the room. On the upper part of these cylinders there is an inverted cone, with a pipe passing through the ceiling and roof, and protected on the outside by a wind-guard which allows the hot air and products of combustion to escape. By this contrivance the gas is consumed in a very heated atmosphere, and thus there is less necessity for combustion in order to obtain a given amount of light; for, in the generality of cases, a large portion of the gas consumed is employed in raising the air to the temperature necessary for sustaining the ignition of the small particles of carbon contained in the flame. It has been stated by Mr. Edwards of Liverpool that the burners, in this position, do not consume more than half the usual amount of gas; besides which, the intensity of the light is very great. He says that the cost of lighting the sun-burner which is placed over the orchestra of the Philharmonic Hall at Liverpool, is 7½*d.* per hour. This burner contains a hundred and seventy-one small-sized fish-tails, which, under ordinary circumstances, would cost about 1*s.* 1*d.* per hour.

9. *The Common Argand Burner* produces a flame which is exactly like that of an ordinary Argand oil-lamp. The burner consists of a circular disc of iron, pierced with a number of holes. It is hollow in the middle for the purpose of allowing a supply of air to the interior of the flame; and the jets of gas coalesce, so as to form a hollow cylindrical flame. A glass chimney is placed around the burner in order that the supply of atmospheric air may be copious and steady. The number of holes or jets varies from ten to thirty for ordinary gas, and from thirty to ninety for cannel. In the former

case the holes are comparatively large, and in the latter they are very small. When common gas is consumed from an Argand burner, the chimney ought not to be above seven inches in height; but when cannel-gas is burnt, it may be increased to nine or ten inches. If the chimney be too high, the supply of atmospheric air is too great, and the gas is overburnt; whereas, if it be too low, the supply is not sufficient, and then the gas smokes: in either case the intensity of the light is diminished. For ordinary London gas, a burner with fifteen holes, and a seven-inch chimney, is considered to be the best. Such a burner will consume about five cubic feet of gas per hour, and will give the light of fifteen sperm candles.

Several patents have been taken out during the last few years for improvements in this form of burner: they have chiefly been directed to the lessening of the shadow which is cast by the ring and body of the apparatus. Of all these, Platow's is the most important. His burner consists of a mere ring perforated with holes.

10. *The Argand with a Button or Deflecting Disc.*—This form of burner has received various names, according as it has been modified by different patentees. It is called the Winfield burner, Young's burner, Guize's burner, and the Aberdeen burner. The button or disc is composed of copper or iron, and it is placed in the centre of the flame a little above the level of the burner. It acts as a break to the inner current of air, and deflects it outwards so as to enlarge the upper part of the flame, and to give it the form of a tulip (Fig. 50). This kind of burner is only suited for the richer kinds of gas, as cannel gas and naphthalized gas. In some cases the air is deflected to the outside as well as inside of the flame. This is the principle of Guize's burner, and the deflection is effected below the button by means of a bend or constriction in the glass chimney, or else by the aid of a metal cone like that of the solar lamp. In Young's burner there is a series of discs placed one above the other, the discs being successively larger and larger from below upwards; by this means the air suffers a series of deflections, and causes the flame to be most vivid. A burner of this description is particularly well suited for the combustion of very rich cannel gas.

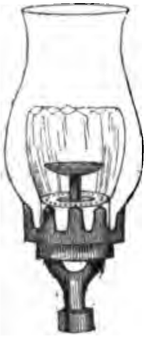
Fig. 50.

11. *The Argand Burner with two or more Rings of Flame, one within the other.*—This is the principle of the Boccius burner; and, from the circumstance that one flame always assists another in promoting the combustion of another, the light from this burner is very considerable. Mr. Carter has obtained a patent for a burner of this description, modified somewhat in its form so as to provide for a due supply of atmospheric air, and also to carry off the products of combustion. The burner consists of a series of Argand flames concentric to each other, with only just so much space between the rings as will serve for the transmission of the necessary quantity of atmospheric air; and over the flames there is placed a conical chimney which carries away the products of combustion. In the concentric burners hitherto used, the object has been simply to obtain the effect of two or more concentric flames, without having due regard to the proper and uniform supply of air to each flame. The consequence of this is, that great and unnecessary quantities

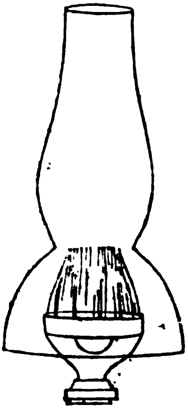
Fig. 51.

of air enter such burners; and the flame is thereby cooled much below the temperature requisite for the perfect combustion of the gas. On this account the intensity of the light is very much below what it ought to be. In Mr. Carter's burners this objection is overcome; for the space between the rings is properly graduated, and the current of air is made to compress the flame and blow in upon it by means of a contraction in the glass chimney—the point of contraction being at such a height above the burner as to produce a bright and steady flame (Fig. 51). The ventilating-shaft is placed over the burner, and communicates above the ceiling with the chimney. It consists of a funnel, and a tube which may be either of metal or glass. These are arranged so as to regulate the supply of air to the flames, and they are enclosed in a chandelier of glass pendants.

12. *An Argand with a Jet of Gas within it.*—This form of burner has been patented by Mr. Billows, who describes it as an ordinary Argand, having a central tube with a single jet, which burns within the hollow of the flame: and, instead of the ring being perforated with a number of holes for the issue of gas, as is usually the case, the ring is contrived with a circular slit, so that there is a continuous sheet of flame in a cylindrical form.

13. *Leslie's Argand* is the very reverse of the last; for the principle on which it is constructed is to allow a current of air to pass up between each of the jets, and so to destroy, to a certain extent, the continuity of the flame. This is effected by a number of small tubes, which rise to the height of an inch or so above the ring which supports them. These tubes are made to converge a little as they advance upwards, and thus they form a truncated cone (Fig. 52). The glasses are constricted, so as to deflect the air into the flame; and they are of different heights, in order that they may be suited to different amounts of consumption. These burners are very well suited for the combustion of cannel gas, but they destroy the light of common gas by over-burning it. The flame should be always managed so as to reach nearly to the top of the glass: for if it passes above it, soot is deposited; and if it does not reach almost to the level of the glass, the gas is over-burnt and light is sacrificed.

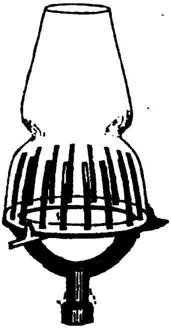

Fig. 52.

14. *The Pinnacle Burner*, of Messrs. Baldwin and Neal, is constructed on somewhat the same principle as the last, only the tubes are very short—they are, in fact, but mere nipples on the top of the ring, and the glass is not constricted (Fig. 53).

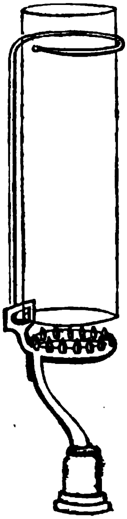

Fig. 53.

Many other varieties of gas-burners have been invented; and as the orifices of the jets are very liable to corrosion from the ammonia and sulphur contained in the gas, Mr. Hallen has proposed that clay or porcelain nozzles should be employed.

The relative values of the several kinds of burners, as employed in the combustion of ordinary London gas, as well as that from cannel coal, may be perceived from the following table. The value is represented as per cubic foot in sperm candles of 120 grains consumption:—

Burner.	Cannel gas: candles per foot.	Common gas: candles per foot.
Single jet	2·6	1·5
Cockspur	3·0	1·5
Fish-tail, No. 1	3·0	1·9
„ No. 2	3·6	2·0
„ No. 3	4·0	2·3
„ No. 4	4·3	2·4
Bat's-wing, nearly the same as fish-tail.		
Leslie, with 28 tubes	3·6	2·7
Gaumont	4·0	2·3
Common Argand, 15 holes	4·0	2·8
Bynner's 28 „	4·0	3·2
Platow's 16 „	4·2	2·9
Guize 26 „	4·2	3·0
Winfield 58 „	4·3	2·8
Billow's, with 3 slits	4·1	2·6

From this it will be seen that the simple jet is the worst kind of burner that can be used for the consumption of gas; next come the smaller-sized fish-tails, then the bat-wings, and lastly the Argands. The Gaumont or double fish-tail, and the Billow's or compound bat's-wing, are also very good burners. But it will be evident from the preceding table, that the burner which is best suited for common gas is not always the one that can be most economically employed for cannel.

The pressure at which gas ought to be consumed is another point of considerable importance: for if the amount of pressure be high, the gas will burn with a roaring noise, and will be consumed wastefully; whereas if it be low, the fish-tail and bat's-wing flames will not be sufficiently spread out, and the light will be dim and smoky. Dr. Letheby states in his Ninth Report to the Corporation of London, that gas ought to be delivered to the public at not less than half an inch of water pressure; and it may be said that in practice this is found to be the best pressure at which gas can be consumed.

Again, it is a matter of importance that the pressure at which gas is supplied to the burner should be as uniform as possible; for if at one time the pressure is great, and at another low, the burner requires constant attention, in order that the flame shall be of one uniform height.

Experiments have been made to determine the rate at which gas burns under different pressures; and as the results are somewhat important, they are tabulated below. In a general way, it may be said, that by doubling the amount of pressure, we increase the consumption of gas by about half.

Burner.	Pressure in inch of water.	Consumption per hour.
Single jet	0·30	2·6 cubic feet.
„ „	0·60	3.9 „ „
„ „	1·20	5·2 „ „
Small fish-tail	0·34	1·4 „ „
„ „ „	0·77	2·2 „ „
Large „ „	0·48	2·3 „ „
„ „ „	0·97	3·3 „ „
Large bat's-wing	0·70	3·1 „ „
„ „ „	1·40	4·5 „ „

Dr. Fyfe has also observed that there are certain constant relations between *the specific gravity* of a gas (that is, its goodness) and *the pressure* at which it is burnt, and *the time* required to consume it—that is, provided we use a jet of a given size, and take care that the flame is of a given height. The jet which he prefers, is one having a hole the fortieth of an inch in diameter; and the height of the flame should be five inches. These relations are as follow:—

1st. The consumption of gas in a given time is as the square root of the pressure; and, consequently, the time required for the consumption of equal volumes, is inversely as the square root of the pressures.

2nd. The specific gravity of the gas is also inversely as the square root of the pressures.

So that if we determine, by experiment, what time it takes for a given volume of gas, of known specific gravity, to burn from a jet of the given size, with a flame of the given height, we are then in a condition to tell the specific gravity, or the rate of consumption, of any other gas, provided it be burnt under the same circumstances, and we observe the pressure. This will be manifest from the following table:—

Pressure in inch of water.	Consumption per hour.	Specific gravity.
0·6	0·67	·841
0·7	0·72	·779
0·8	0·77	·729
0·9	0·81	·687
1·0	0·86	·652
1·1	0·90	·622
1·2	0·94	·595
1·3	0·98	·572
1·4	1·02	·551
1·5	1·05	·532
1·6	1·09	·515
1·7	1·12	·500
1·8	1·15	·486
1·9	1·18	·472
2·0	1·21	·461

By means of this table, we are able to determine the rate at which gas is burning, or its specific gravity, by merely observing the pressure which is necessary to obtain a flame of the given height. In conducting the experiment, the pressure-gauge must of course be on the jet side of the tap. Dr. Fyfe suggests that we may, by operating in this manner, do away with the necessity for a meter or a photometer, or both, and that we may arrive at results which are approximatively correct. Of course it must be understood that the gas is of the usual quality, free from carbonic acid and atmospheric air.

When coal-gas is supplied to the consumer at pressures which are variable, or inconveniently large, the difficulty may be overcome by using instruments which are called *governors* or *regulators*. In some small towns the only means that are adopted for regulating the pressure of gas, is that of taking off or putting on the weights of the gasometer. But as this is a very inconvenient, and at the same time ineffective mode of regulating the supply of gas, it is usual in all large manufactories to employ a governor at the works themselves. This is a small gasometer working very easily and truly in a tank or cistern of water. It is furnished with two pipes—one for the inlet of the gas and the other for the outlet. The former is situated in the centre of the apparatus; and it is provided with a conical or parabolic valve. This consists of a conical or parabolic cavity or socket, in which a solid plug of the same form fits very accurately. The plug is attached to the top of the gasometer, and the inlet-pipe containing the socket is fixed to the bottom of the instrument: consequently, as the gas-holder rises and falls, it carries the plug with it, and so opens and shuts the conical valve; by which means the supply of gas is regulated. Any amount of pressure short of that at which the gas is received into the apparatus, may be communicated to the delivery-pipe by means of weights that are put upon the top of the gas-holder; and as the governor is always placed between the large gasometer at the works, and the pipes constituting the street mains, the pressure of the gas in the latter is regulated in a tolerably effective manner. It would be very effective, indeed, if it were not that there is a rapid taking off of pressure from the gas in the mains by the turning on of the consumers' lights. This causes such a sudden and enormous abstraction of gas from the mains, that the pressure immediately falls. For example:—In the early part of the evening, just before the lights of the neighbouring shops are turned on, the gas in the mains has a pressure of from one inch to one inch and a-half of water; but as soon as the supply is opened to the several burners of the locality, the pressure immediately drops to less than half an inch of water; and then again, when the lights are in great part turned off, the pressure quickly rises. This occasions much inconvenience to those who are burning gas in an economical manner; for it demands constant attention to keep the flame at its proper level. To remedy this, a smaller kind of governor is often used by the consumer himself. There are various forms of this instrument, but they are nearly always constructed on the same principle as the large one. They contain a valvular aperture, which opens or shuts according to the supply at the burners. This is effected either by the plug and socket already described, or by means of a disc which rises and falls over a small aperture. The first mode of constructing the governor was patented by Mr. Clegg, as long ago as the year 1815, and it constitutes the principle of most of the wet governors of the present time. Of these, one of the simplest in its construction is that manufactured by Mr. Glover. It is represented in Fig. 54. *f* is the connection by which it is fixed to the meter, and the gas passes through the pipe *g* into the gasometer *d*. At the top of the pipe *g*, there is a conical valve *i*, *h*, the plug of which is fixed to the top of the little gasometer *d*; and, consequently, as the gas enters the latter and lifts it out of the water in which it floats, the valve is closed. *p q* is a rod fixed to the top of the gasometer, and projecting beyond the cover of the instrument; it serves for holding weights, *r r*, which press down the gasometer, and communicate any amount of pressure that may be required.

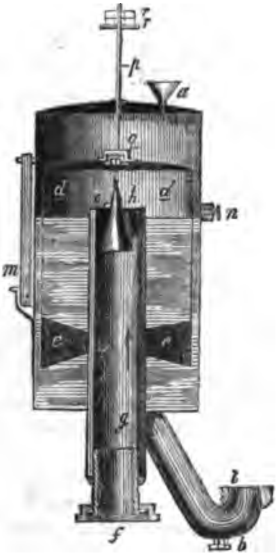

Fig. 54.

The gas escapes from *d*, through the outlet pipe *l*—water is poured into the apparatus through the funnel *a*, and it is kept at a proper level by the tube and plug *n*, while the gauge *m* enables the observer to note at what height the level of the water stands. Lastly, there is a plug at *b* to draw off any water which may happen to spill over or condense in the outlet pipe *l*. When the gas enters the chamber *d*, it lifts the gasometer, and with it the plug *h*, so that the aperture *i* is then closed. Directly the gas is let out from the chamber to the burners by the delivery tube *l*, the weights *r r* on the rod *p* immediately depress the gasometer, and then the valve is again opened for the entry of more gas; and thus, according to the weights at *r r*, and the supply to the burners, will the gasometer be rising or falling, and so keeping up a uniform supply and pressure.

In the governor which has been constructed by Mr. King of Liverpool, the gasometer is made rather heavy, and it is suspended to one arm of a very nicely moving beam, like that of a pair of scales, while weights are attached to the other arm so as to regulate the degree of pressure.

In Mutrel's governor the beam is within the body of the instrument (Fig. 55), and the gasometer floats in an exterior vessel or chamber of water, while the pressure is regulated by a weight *a*, which slides backwards and forwards on an external beam.

The American regulator, invented by Dr. Kidders, is constructed on the same principle, though the gasometer floats in quicksilver instead of water, and the valve is discoid in lieu of being conical.

The governor which is patented by Messrs. Hulett and Paddon contains the beam within a horizontal tube, and the weight floats upon the surface of quicksilver, so that the pressure of the gas may be made to regulate itself. This instrument is shown in Fig. 56; and it will be seen that when the gas from the main enters the chamber A, it will by its pressure force down the surface of the quicksilver at D, and this will cause the plug or weight C to fall, and consequently the valve B at the other end of the beam to rise and so to close the aperture which transmits the gas to the burners. There are caps at F and G to be removed when the counterpoise is to be regulated to any other pressure.

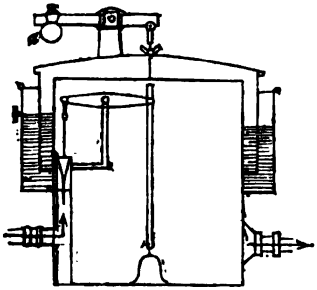
Fig. 55.

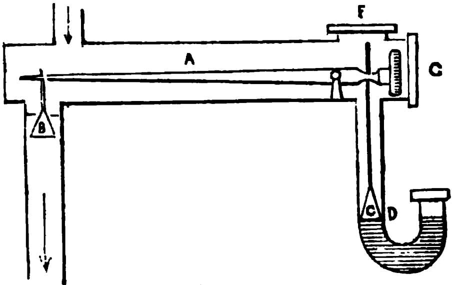

Fig. 56.

Mr. Poole has taken out a patent for the use of a succession of small governors, in order that the supply may be still better regulated; and Mr. Platow has constructed a dry governor which works without any fluid at all. Lastly, Mr. Biddel has contrived a burner which regulates itself. It consists of an ordinary Argand, with a compound bar of brass and iron. The bar is formed of a brass tube with a central rod of iron; the latter is attached to the top of the former, and plays freely within it. When the burner is lighted, the bar stands up in the middle or hollow of the flame; and as these metals expand unequally for the same temperature, the motion of the longer rod is communicated to a small lever so as to move a plug which opens or shuts the aperture that delivers the gas. The temperature of the flame is thus made available as a means of regulating the supply of gas, and so of keeping the flame at one uniform height. After the burner has been once set, so as to produce the necessary amount of light, any increase in the supply of gas will immediately increase the size of the flame, and this will cause the bar to expand and act on the plug so as to shut off a portion of the gas. On the contrary, if the supply is not sufficient, the bar contracts, and then the aperture is opened.

ON THE GENERAL MANAGEMENT OF GAS, VENTILATION, &c.

General Management of Gas.—On the Continent, the government or municipal authorities enforce certain regulations for the management and distribution of gas. In Hamburg, for instance, the gas-fitters are obliged to perform their work in a certain manner: they must use tubes of wrought-iron, brass, or copper; and in cases where these are not very easily adapted, tubes of drawn-tin may be employed. The joinings must be made in a durable and solid manner, either by means of sockets ground in and cemented with iron cement, or by screwing up, or by soldering. Any other mode of connection is forbidden. The tubes must be placed in localities where they are accessible, so that in case of leakage the mischief may be easily remedied. The cocks must be arranged in such a manner that they only make the fourth part of a turn, and they must be fixed so as not to be removeable from the barrel. The gas-meters are to be furnished by the gas company, and examined and stamped by the adjusting commissioner. In case of fire, all the tubes of one inch or more in diameter should have a stop-cock, so that they may be shut off from the main-pipe. No one is allowed to make use of his gas-fittings until the gas-fitter has tested their soundness, by means of a pressure of one inch of mercury or fourteen inches of water. All the gas-fitters are sworn to adhere to these instructions; and in case of any damage resulting from negligence on the part of the fitter, private persons are entitled to enforce their claims against the gas-fitter before a civil court of justice.

In a supplemental notice attached to the contract made between the English Gas Company in Paris and its consumers, the following regulations are recommended:—"To prevent any inconvenience in the use of gas, it is requisite that the burners should not allow any gas to escape in an unconsumed or imperfectly-consumed state. This result is obtained by maintaining the flame at a moderate height—three inches and a quarter at most, and confining it within a glass chimney of eight inches in height. The rooms lighted should be carefully ventilated, even during the cessation of lighting, by openings in the ceiling, through which the gas and its burnt products may escape. The plugs of the cocks should be greased from time to time, so as to prevent oxydation, and to facilitate their working.

"In *lighting* the gas, it is essential to open, in the first instance, the maincock, and then to apply the light successively to each burner at the moment of opening its cock, so as to prevent the escape of any unconsumed gas.

"In *extinguishing the light*, it is better first to close the maincock, and then to shut off the taps at each of the burners. Whenever a smell of gas indicates that there is a leak in the pipes, the doors and windows should be opened, so as to cause a current of air through the room; and the maintap should be closed. The consumer should abstain from searching for any leak with a light, but he should rather give notice to the company and the gas-fitter. In case, whether by imprudence or by accident, the escape shall have been ignited, the best means of extinguishing it is to cover the aperture with a wet cloth."

These rules are of great importance, for very serious accidents have resulted from the explosion of gas mixed with atmospheric air. A few years ago—namely, in the month of August, 1848—a fearful disaster of this description occurred in Albany Street. The gas accumulated in the shop for a very short time only—in fact, it had been escaping no longer than one hour and twenty minutes from a crack in the meter; the area of the room was about 1620 cubic feet; but when the gaseous mixture ignited, it blew out the entire front of the premises, carrying two persons through a window into a back yard, and forcing another by the violence of the shock on to the pavement on the opposite side of the street, where she was picked up dead. For more than a quarter of a mile on each side of the house the effects of the explosion were severely felt, and the glass in most of the windows of the neighbourhood was shattered. But the most extraordinary evidence of its enormous power was exhibited in the condition of the premises which immediately faced the house that was destroyed: in one of these the iron railings around the area were snapped asunder, and in another a part of the roof and back windows were carried to a distance of from 200 to 300 yards; besides which, the pavement was torn up for a considerable length. According to the official reports which were made to the insurance offices, it appears that 103 houses were injured by the explosion, and that the damage done amounted to £20,000.

Another accident of a similar kind occurred in the month of July, 1850, at the Ilford toll-gate, whereby three persons were severely injured. The space in which the gas accumulated had an area of eighty cubic feet, and the gas had been escaping into it at the rate of forty cubic feet an hour for a period of fifteen minutes. A piece of lighted paper was incautiously introduced for the purpose of seeing where the leak was, and the mixture immediately exploded, breaking up the flooring of the room, blowing out the window, and knocking down a large portion of the front and partition walls of the building. These accidents were made the subject of scientific investigation, and reports were furnished to the journals by Dr. Arnott, Dr. Letheby, and Dr. Alfred Taylor. In speaking of the latter, Dr. Letheby says—"It is difficult to form an estimate of the total explosive force exerted by the gas on this occasion; but I am led to think that it was probably equal to about twenty tons—for when a column of mixed gas, consisting of one part of coal-gas and seven of air (the proportion in this case), is fired, it expands to about five times its bulk, and exerts a pressure of about four pounds on the square inch." In the report given by Dr. Arnott on the explosion in Albany Street, it is stated that the strongest explosive mixture consists of one part gas and ten atmospheric air, the expansion being in that case tenfold; and in a report furnished by M. Tourdes on the explosion which took place at Strasburg in 1848, it is stated, that the greatest force results from a mixture of one part of gas and eleven of air. These discrepancies doubtless arise from the variations in the composition of coal-gas; but it may be stated, in a general way, that from seven to eleven parts of air to one of gas constitute the most dangerous proportions; for if the gas or the air be much in excess over these, the force of the explosion is very much diminished. This is exemplified in a very striking manner by the admirable researches of Sir Humphry Davy into the explosive properties of light carburetted hydrogen, or *fire-damp;* for they show that while seven or eight parts of air to one of gas produce the greatest explosive effect, other proportions are less dangerous: in fact, a mixture of equal parts of gas and air will burn, but it will not explode. The same is the case with a mixture of two of air, or even three of air, and one of gas; whereas four of air and one of gas begin to show an explosive tendency, and this becomes more and more marked up to seven or eight of air to one of gas. His experiments also prove that one part of gas to ten, eleven, twelve, thirteen, or fourteen of air were also inflamed, but the violence of the combustion became less and less; and when the mixture consisted of fifteen parts of air to one of gas, there was no explosion at all.

These results indicate that the most easy way of destroying the inflammability of coal-gas, is the mixing of it with a large proportion of atmospheric air; and hence the necessity for good and effective ventilation wherever there is an escape of gas. We can recognize the odour of gas long before the mixture acquires explosive properties. Dr. Alfred Taylor states that the smell of gas is perceptible when it is mixed with five hundred parts of atmospheric air; and that it is very manifest when it forms one part in a hundred and fifty of air. We have, therefore, a ready means of discovering the danger; and, indeed, the offensive odour of coal-gas is one of its most valuable properties; for if it were to be deprived entirely of its odour, accidents would be far more frequent than they are at present.

As gas is lighter than atmospheric air, it is always disposed to accumulate in the upper part of the room; and here it is that ventilation will be most effective. Still, however, there is a strong diffusive power possessed by all gases, by virtue of which they rapidly comingle; and hence the necessity for a complete displacement of all the atmosphere of a room in which coal-gas has been escaping.

Dr. Taylor attaches importance to the poisonous properties of coal-gas, saying that there are reports of six deaths on record, where persons have been killed by sleeping in rooms near to which there was a leakage of gas. M. Tourdes found that an atmosphere containing one-thirtieth, or even one-fiftieth, part of coal-gas seriously affected animals. It cannot, therefore, be too strongly impressed upon the minds of those who use gas in dwelling-houses, that where a smell is perceptible, the defect should be immediately found out and remedied. When the leakage is comparatively slight it may endanger the lives of those who sleep in or near the spot; and when it has reached a higher point, it may lead to a serious accident by explosion. The effects which it produces on the human system are those of depression, headache, sickness, and general prostration of the vital powers, followed by deep coma.

Gas Ventilation.—It has been already stated that the products of gas combustion are very pernicious—that they not only cause discomfort to the feelings, and perhaps injury to the health of those who inhale them, but they are also very destructive to property; besides which, the high temperature which is produced in rooms where gas is burnt in a wasteful manner, is very objectionable. All these circumstances render it necessary that the products of combustion, as well as the heated atmosphere, should be removed as speedily as possible. In fact, it is of the greatest importance that gas should be consumed in such a manner as not to affect the atmosphere of the room at all. Several contrivances have been suggested for the purpose of effecting this.

Many years ago, when the books in the library of the Athenæum Club-house were found to have been impaired by the gas used in the building, Professor Faraday invented an apparatus which was found to remedy the evil. It consists of an ordinary bat's-wing, or fish-tail burner, enclosed in a globe or bell-glass, closed at the top with mica; the interior of the globe communicates with a tube, which surrounds the gas-fitting, and passes away through a condensing cistern to a ventilating-shaft. The tubes are so arranged as not to be visible, and the burners are suspended in the ordinary way from a chandelier. By this contrivance the gas burns in a closed chamber, and the products of combustion are at once carried away. This plan of consuming gas is practised at the club-house before mentioned, and also at Buckingham and Windsor Palaces; but the great objection to it is the frequent breaking of the glasses, and the necessity for a ventilating shaft with a strong upward current.

The *sun-burner*, which is in use at the Philharmonic Hall at Liverpool, has already been described, and so also has the ventilating burner of Mr. Carter (see Fig. 51). Messrs. Whichcord and Rosser have also patented a contrivance for effecting the same purpose; it consists of a ventilating-bell and draught-tube placed over the burner. If the bell is lowered so as to be a little below the level of the glass chimney, and the whole surrounded by a glass globe which is open only at the top, a current of atmospheric air passes down over the tube and chimney, and thence to the flame, where it is consumed, after which it passes away through the draught-tube. By this means the air is heated before it reaches the flame, and therefore the intensity of light is augmented; besides which, the cooling influence of the air on the draught-tube and chimney prevents the heat of the gas from being communicated to the room.

Another mode of effecting ventilation, is to place a simple catch-tube, or funnel, over the gas, and thus to carry away the products of combustion into a neighbouring chimney, or to the outside of the house. The draught-tube need not be very large, and it may be hidden above the ceiling. When this plan is not available, a less perfect mode of ventilation may be adopted by boring a number of holes through the ceiling immediately over the chandelier or burner. The holes should be about half an inch in diameter, and they should communicate with the space above the ceiling. A few ventilating bricks should also be introduced into the wall, bounding the space on each side of the house, so as to carry off the warm air. The holes in the ceiling may be hidden from view by means of a perforated or open rosette.

Lastly, where gas can be burnt out of the room altogether, it is of the greatest importance that no plan of internal combustion should be adopted. Shop-windows, for example, are best lighted by means of an external jet with a reflector. On the Continent this is the plan very generally employed; and it is found to produce a much more pleasing effect, than when the burners are placed on the inside of the windows. One of the best forms of lamp for this purpose is that manufactured by Mr. Reichenbach, of the Borough Road. It is arranged so as to diffuse the light very perfectly, and it has an adjustment whereby the reflector may be placed at any angle. There is no reason why gas may not be used in a somewhat similar way for illuminating private rooms. At present we generally receive the light from the ceiling, and the combustion takes place in the atmosphere of the room; but it is quite possible to burn the gas in a closed chamber at the side of the room; say, for instance, in a recess which might be formed by removing a portion of the wall in some convenient situation, as between two windows. This recess might have a number of small gas-burners with reflectors behind them; and it might be covered in front with ground-glass, ornamented with some device. It should, of course, communicate with the external atmosphere, and be shut off from the room. By day it might be covered by a mirror; and at night the mirror might be slid to one side, so as to form a shutter for a window. Again, in some situations where the space between the ceiling and the upper floor is very considerable, a ring of gas jets, or a sun-burner, might be introduced into a closed chamber in the ceiling, and the light might be reflected or diffused in a very agreeable manner. In short, there are many plans which might be suggested for a more perfect and wholesome mode of burning gas for illuminating purposes than that which we generally employ; and there is no doubt that if attention were sufficiently aroused to the importance of this subject, many improvements would be adopted.

Vitiating Effects of Illuminating Agents.—Although gas is generally regarded as the most injurious of all light-giving bodies, yet this is not true when we consume it in moderation; that is, when we burn it in such a manner as to obtain the same amount of light as we are accustomed to have from other agents. This will be made evident from what follows. A very little consideration will show that we have become exceedingly wasteful in the use of gas, burning it in situations where we obtain the least possible advantage from its luminous effects, and demanding such a strong glare from it, that there is a much larger consumption of the material than need be; and consequently there is a larger vitiation of the atmosphere than would occur with any other illuminating agent. Take the case of an ordinary sitting-room. With two candles on the table, at a distance of a foot from the observer, he can see well enough to read, write, or work. But suppose that gas is introduced into the room: it is placed in a chandelier four or five feet from the table, and then, according to the law of intensity, it requires twenty-five candles' worth of light to give the same amount of luminosity on the table; and so two or three gas-burners, consuming in all about ten cubic feet of gas per hour, are fitted up to do the work of two candles. It is this profusion of light and heat which has occasioned so strong a prejudice against the employment of gas, on the score of its heating and vitiating effects; but the prejudice is not well-founded. Dr. Frankland has made experiments to determine the relative amounts of carbonic acid produced by the usual illuminating agents, and he states that the following proportions of carbonic acid are produced per hour during the combustion of a sufficient quantity of each of the materials to get the light of twenty sperm candles, each burning at the rate of one hundred and twenty grains per hour:—

Tallow	10·1 cubic feet.
Wax	8·3 „ „
Spermaceti	8·3 „ „
Sperm oil	6·4 „ „
Common London gas	5·0 „ „
Manchester gas	4·0 „ „
London cannel-gas	3·0 „ „
Hydrocarbon Boghead gas	2·6 „ „
Hydrocarbon Lesmahago gas . . .	2·3 „ „

Now, if we bear in mind that each cubic foot of carbonic acid involves the destruction of nearly five cubic feet of air, and that, according to toxicologists, a proportion of five per cent. of carbonic acid in the atmosphere is dangerous to animal life, we shall perceive that there is an enormous amount of atmospheric air vitiated and rendered irrespirable from this cause alone; but to this must likewise be added an almost equally large quantity of oxygen which is consumed by the hydrogen of these illuminating agents, and which in coal-gas amounts in many cases to nearly fifty per cent. It will be manifest, therefore, that in obtaining artificial light by any of these means, we destroy a large quantity of atmospheric air; and hence provision should be made for an ample supply of it by means of good ventilation. This will be still more evident from what follows.

Mr. Lewis Thompson has instituted a set of experiments for the purpose of ascertaining how long a flame of a given intensity, obtained from different illuminating agents, will burn in a given bulk of atmospheric air. In all cases the value of the light emitted was the same—namely, that of thirteen standard sperm candles, each of one hundred and twenty grains' consumption per hour; and a distinct experiment was made with each agent. The times that elapsed before the flames were extinguished were as follow:—

Rape or colza oil	71 minutes.
Olive oil	72 „
Russian tallow	75 „
Town tallow	76 „
Sperm oil	76 „
Stearic acid	77 „
Wax candles	79 „
Spermaceti candles	83 „
Common coal-gas	98 „
Cannel coal-gas	152 „

These times are inversely as the salubrity of the illuminating agent; and hence it follows that common rape oil is the most destructive of the atmosphere, and rich cannel-gas the least.

The same is true of the heating effects of these bodies. Already we have alluded to this fact; but as it has been made the subject of special experiment by Mr. Lewis Thompson, we will again refer to it. He says that when the following materials are burnt for an hour, in such quantity as to give the light of one sperm candle of one hundred and twenty grains' consumption, they raised the following amounts of water from the temperature of 60° to 212° Fah.:—

Cannel-gas	raised	4074	grains	of water	152°
Common gas	„	6840	„	„	„
Sperm candle	„	7305	„	„	„
Tallow candle	„	7534	„	„	„
Colza oil	„	7870	„	„	„

"The impossibility of maintaining one uniform rate of consumption in the case of the candle and oil, detracts slightly from the value of the results; but the indications are too decisive to permit the general conclusion to be doubted—that, light for light, the inconvenience arising from heat is much less with gas than with any of the ordinary agents employed to give light; and in the case of cannel-gas the advantage is very great."

ILLUMINATING AGENTS WHICH DO NOT VITIATE THE ATMOSPHERE.

Of these there are two which are especially deserving of notice: these are the oxy-hydrogen, or Drummond light, and the electric-light.

The Oxyhydrogen Light.—This was first introduced to public notice by Lieut. Drummond. It consists of a jet of oxygen and hydrogen gases, or of alcohol and oxygen, burning so as to ignite a piece of lime or magnesia; and the high temperature which is thus produced renders the earthy body so incandescent as to be intensely luminous.

The apparatus which is employed for the production of this light has, at various times, undergone considerable alteration and improvement. Originally the mixed gases, consisting of two parts, by measure, of hydrogen and one of oxygen, were condensed, by means of a syringe worked at great pressure, into a square metal box, from which there issued a long jet, of very small bore; this jet passed through a thick oak partition, in order that the operators might be protected from the danger which was incidental to the bursting of the metal-box from explosion. This was the form of apparatus originally contrived by Clarke and Newman. After this the safety-jets of Gurney, Hemming, and others, were adopted; and at the present time it is customary to burn the mixed gases by means of the latter, or else to deliver the gases separately into a double jet or nozzle, where they mix immediately before they are consumed. Both of these plans are very manageable, though the latter is thought to be less open to the risk of explosion than the former.

The hydrogen gas is obtained by acting on zinc with dilute sulphuric acid (one of acid to ten or twelve of water); and the oxygen, by heating a pulverulent mixture of four parts of chlorate of potash and one of peroxide of manganese in a glass retort. In each case the gas is to be collected in a gasometer, or else in bladders fixed to receivers over a pneumatic trough. Mr. Watson has obtained a patent for procuring the gases already mixed in proper portions by the decomposition of water by galvanic agency; but the process is an expensive one.

When the mixed gases are burnt, the flame is projected upon a small cylinder of lime or magnesia, which is from time to time turned round, so as to expose a fresh surface to the action of the flame.

Another mode of obtaining this light is to throw a jet of oxygen into a flame of spirit of wine or ether, or to mix the oxygen with coal-gas instead of with hydrogen.

The light which is obtained by either of these plans is very intense. When concentrated by means of a concave mirror, it is distinctly visible at a distance of sixty-five miles; and it is calculated that when it is compared with the light of a wax candle, the mixture of oxygen and coal-gas is equal to twenty-nine of such candles, that of alcohol and oxygen to sixty-nine, that of ether and oxygen to seventy-six, and that of hydrogen and oxygen to a hundred and fifty-three. In consequence of the great intensity of the oxyhydrogen light, it is generally employed for the phantasmagoria, the dissolving views, the solar microscope, and for theatrical illuminations, and experiments in optics; besides which, it has been recommended for light-houses and signal-lights. The light differs from all others which have been described, in the circumstance of its being exceedingly white, and therefore well suited for the display of bright and delicate colours. With this light the various shades and tints of a picture or dress are as plainly discernible as they are by the diffused light of day.

The Electric Light.—Within the last few years public expectation has been raised to a great height by the announcement that voltaic electricity might be made the means of producing a very pure and intense light; and several patents have been taken out for the purpose of accomplishing this. Indeed, many exhibitions of the light have been made at several public institutions, and also in the open air, by which the sanguine hopes of its originators have been apparently increased. Of late, however, little has been heard of the subject beyond the few remarks which occasionally fall from men of science in their discourse upon it.

The idea of employing electricity for this purpose is not novel; for the power of the voltaic light was thoroughly investigated in the time of Sir Humphry Davy; but the difficulties which electricians had then to contend with in the inconstancy of the galvanic battery, offered an insurmountable barrier to its use. A part of this difficulty was overcome by the late Professor Daniell, who was the first to contrive a constant battery. Since then the voltaic arrangements, by which a current of electricity of great power may be sustained for any length of time, have been improved by Mr. Smee, Professor Grove, M. Bunsen, and the Rev. Professor Callen of Maynooth; so that at the present time there are abundant facilities for producing the light.

The first patent which was taken out for the use of electricity for illuminating purposes, was that of Mr. Staite in November 1846. In July 1848, he obtained another patent for an improved form of battery. This he called the *perfluent* battery, in contradistinction to the *percolating*, which was already in use. It was thus named on account of the arrangement which he adopted for keeping up a supply of acid. The troughs, or cells of the battery, communicated with each other by means of elastic syphons or cross tubes, and the acid was made to flow from cell to cell throughout the entire length of the series, so that when it arrived at the last cell it was completely exhausted of its exciting power, and saturated with zinc. It was thought that such an arrangement would be the means of economizing power and material; but it happens to be the very worst that could possibly have been contrived for such a purpose. The electrician knows that if he requires the greatest power from his battery, each of the cells must be acting alike and to their fullest extent; for it is the condition of electricity to multiply itself, not after the ratio of the most powerful cell, but after that of the weakest. If, therefore, we have in the arrangement a number of cells working differently, as is the case in the perfluent battery, the activity of the one set of cells will be of no avail in raising the inactivity of the other; for the least powerful cell governs all the others, and reduces them to its own standard. It follows, therefore, that the last cells in Staite's arrangement must act as clogs on the first; for, as they are almost without action, they must reduce the power of the first cells to little or nothing. Another alteration, proposed by Mr. Staite, was that a liquid amalgamation of zinc and mercury should be used in bags, or porous cells, in lieu of the ordinary form of amalgamated zinc. He also suggested the use of a solid amalgam consisting of 5 of zinc and 1 of mercury. He likewise proposed that lead should be employed instead of zinc, in order that valuable products might be obtained. All these suggestions, however, are of no value; for they are contrary to the principles on which a good galvanic battery ought to be constructed.

In July 1848, the Chevalier Alexandre Edouard Lemolt also took out a patent for improvements in the batteries and apparatus used in obtaining the electric-light. His improvements in the battery were but modifications of those long since adopted by Professor Bunsen. He employed plates of carbon, which were either cut out of the hard coke which lines the interior of gas-retorts, or else formed by powdering the coke, mixing it with a little coal-tar, then pressing it into a mould and baking it at a low red heat. Since then—namely, in the month of February 1849—Mr. Charles Thomas Pearce obtained another patent for improvements of a like description. His battery was a perfluent one, and it differed from Staite's in the circumstance that the flow took place separately in each cell, and not from cell to cell; so that the amount of power generated in each cell was the same, and his porous diaphragms were made of sycamore wood, soaked in dilute acid. Another of his claims was the use of alkaline salts in solution, which did away with the necessity for amalgamating the zinc. Lastly, another patent has since this been obtained by Messrs. Staite and Petrie, wherein they recommend a modification of their former arrangement, so as to keep the liquids in all the cells of the same degree of strength. Each of these patentees has likewise secured to himself the use of certain contrivances, whereby the charcoal-points which emit the light shall be removed and kept at a proper distance from each other. These, in fact, constitute the real claims to consideration; for the batteries which they have invented are not worthy of the least attention.

Batteries used in obtaining the Electric Light.—(*a.*) *Daniell's Battery*, which consists of a jar containing a cylinder of sheet copper, and a saturated solution of its sulphate; within this there is placed a porous cell (composed of brown paper, unglazed earthenware, or bladder), which holds a cylinder of sheet zinc, and a solution of common salt. These are arranged so as to obtain both quantity and intensity of electricity.

(*b.*) *Grove's Battery* is constructed in a very different manner. The outer cell is of an oblong form, and it may be made of glass, earthenware, or gutta-percha. It contains a piece of sheet zinc bent into the form of the letter U, one leg being a little longer than the other. The zinc is amalgamated according to Mr. Smee's plan, by dipping it into dilute sulphuric acid, and then covering it with quicksilver. Within the bend of the zinc there is placed a porous oblong cell of unglazed earthen ware, and within this a sheet of platinum. The battery is set in action by pouring dilute sulphuric acid (in the proportion of one acid to seven water) into the zinc compartment, and strong nitric acid into the platinum cell. As before, the battery is to be arranged for quantity as well as intensity.

(*c.*) *Bunsen's Battery*, as well as that modification of it proposed by M. Lemolt, is truly a Grove's battery, with a piece of charcoal instead of the sheet of platinum.

(*d.*) *The Maynooth Battery*, which was contrived by the Rev. Professor Callen of Maynooth, is also a modification of Grove's principle; for a plate of cast-iron is used instead of platinum, and the cast-iron cell is charged with a mixture of two parts of strong sulphuric acid, one and a half of nitric acid, and the same of water; and it is better to excite the zinc with a strong solution of muriate of ammonia instead of with dilute sulphuric acid, for this does away with the necessity for amalgamating the zinc.

Professor Grove says that the result of his experience is, that the nitric acid battery, in one or other of the preceding forms, is the only one hitherto invented which offers anything like a practical means of applying this power to illuminating purposes; and the best arrangement that can be adopted for obtaining the greatest amount of power is to use about forty or sixty cells, arranged in two series of twenty or thirty each. By this means we have the quantity of two cells, and the intensity of twenty or thirty. If we go beyond this in the intensity arrangement, the fluids in the cells begin to boil and quickly to evaporate. This is objectionable; for it not only renders the atmosphere of the room irrespirable, but it frequently brings the action of the battery to a stand-still. The source of power in all cases is the chemical action which takes place in the cells.

Mode of Obtaining the Light.—The wires which convey the electricity from each of the series must be connected, so that the two positive poles are brought together and the two negatives. The wires should be of large size, so as to conduct the electricity with ease; and they should be covered with gutta-percha, so as to insulate them. If this precaution is not taken they may touch each other, and so cut off the current; or they may become unmanageably hot; or they may communicate a shock to the operator. It is usual to have the galvanic batteries in any convenient place at a distance from the experimenter, and to convey the electricity, by means of the insulated wires, to the point where it is wanted. Light may be obtained from the battery in two ways: either by bringing the poles into contact with a yard or so of platinum or iridium wire, wound into the form of a spiral; or by terminating them with cylinders of charcoal, and then bringing them into contact. In each case the light is produced by the ignition of the conducting medium. Platinum or iridium is not so well suited for the purpose as charcoal, because, in the first place, the light is never so vivid, and, in the second place, the metal is very likely to fuse, and put a stop to the experiment. When charcoal is employed, it is found that the greatest intensity of light is produced by drawing the points apart to the extent of from a quarter to half an inch; and then there is a stream of finely-powdered charcoal, in a most intensely ignited state, projected from one pole to the other, forming an arc of flame. If the charcoal-points are too close together, we do not obtain the maximum effect; and if they are too far apart, the arc is broken, and the light extinguished. This it is which constitutes the difficulty in keeping up the electric-light, and which gives to the flame its unsteady, flickering character. Consequently, all the contrivances which have been adopted for overcoming this have been made the bases of the several patents to which we have alluded. These we shall now proceed to describe.

Apparatus for sustaining the Electric Light.—The first of Mr. Staite's patents was for a contrivance or method for maintaining the charcoal-points at an uniform distance. One of these is represented in Fig. 57: *a* and *b* are the charcoal-points; they slide easily in a brass tube which holds them, and their free ends rest upon a solid cylinder of plaster of Paris *c*. At the opposite ends they are pressed upon by a spiral spring, which is contained within the brass tube; and by which means they are always forced down very firmly on the plaster of Paris cylinder. There is an adjusting screw at *d* for regulating the distance of the points, and the arms *f g* convey the current. To set it in action, the two charcoal-points are made to touch by means of the adjusting screw *d*, and then they are separated to the required distance, so as to get the maximum amount of light. As the points burn away, the springs keep up a fresh supply by forcing them down on the plaster of Paris cylinder, and maintaining them at their proper distance. It was at first thought that this arrangement would meet all the difficulties of the case; but it was soon found that there were irregularities in the action of the battery, as well as a projection of the charcoal from one pole to the other, which demanded a constant motion of the points; and, therefore, a few months afterwards the patentee adopted

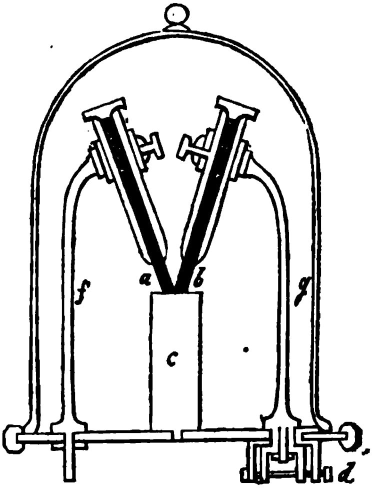

Fig. 57.

another invention, whereby the points were adjusted by the aid of an electro-magnet. A third patent, with still further improvements in this respect, was obtained in the course of the same year. In this last patent there are three distinct kinds of apparatus described for the management of the electric-light—namely, one for obtaining a regularly intermitting light, another for procuring a constant and uniform light, and a third for developing a constant light by the ignition of a metallic wire.

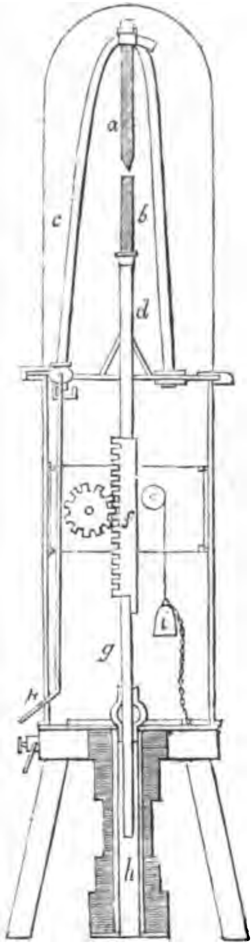

Fig. 58.

The apparatus for producing the first effect is represented in Fig. 58: *a b* are the two charcoal-points; one of them is fixed to the conductor *c*, and the other to the moveable rod *d*. The lower part of *d* is fixed to a rack *f*, and this to an iron rod *g*, which moves freely up and down in a tube *h*, that is surrounded by a coil of wire in the form of a helix: a weight *i* is attached to the rod *f g* by means of a string, which passes over a pulley. The object of this is to counterbalance the weight of the rod, rack, and charcoal-holder; and there is a small piece of chain also attached to the weight, so that the balance may be equalized as the rod is pulled down. The action of the apparatus is as follows:—The conductor *k* and the wire of the helix around *h* are brought into connection with the galvanic battery, and the circuit is closed by bringing the two charcoal-points into contact. At this moment the iron rod *g* is rendered magnetic, and is drawn down into the hollow tube within the helix. By this means the charcoal-points are separated, and a most intense light is produced; but soon the separation takes place too far, and then the circuit is broken and the light extinguished. The iron bar now loses its magnetism, and the weight draws it up again, so as to bring the charcoal-points once more into contact, when the same phenomenon is repeated. It is obvious that by this contrivance a succession of flashes at regular intervals is produced, and the weight may be so regulated as to maintain any period for the duration of the light and its intermission.

The apparatus for producing a constant and uniform light is shown in Fig. 59. The charcoal-points A B are attached as before—one to a fixed conductor C, and the other to a moveable conductor D; the latter is moved by a rack F F which works into a pinion, and this turns on a spindle with fixed supports. A barrel is attached to the pinion, and over this there passes a string to which the weight G is fastened: by this means the rod and rack D F are counterpoised. To the spindle there is fixed a cogged wheel H and a lever I; the latter carries a double paul, which locks into the cogs of the wheel in either direction. A long horizontal lever K passes over the paul, and moves on the fulcrum L; while it supports at one end a rod M, which is fixed to an iron bar N, and at the other a moveable counterpoise O. The iron bar travels freely up and down in the coil P.

The paul and its lever I are kept in a state of slow vibration from side to side by means of a crank R, which works in a fork at the end of the lever I. This crank is made to revolve by an ordinary train of wheel-work, furnished with an escapement or fly-wheel, and driven by spring-power or by weights. The object of this movement is to elevate or depress the rack F by turning the wheel H.

The mode of action of the apparatus is as follows:—The negative pole of the battery is brought into cantact with the rack and rod D, F, and the positive pole with the coil P, and thence with the upper charcoal support C. Immediately the points touch, and the circuit is completed, the coil raises the iron rod N. This acts on the lever K, and causes the lower charcoal-point to descend and separate from the upper one. Directly the separation has taken place to the maximum extent, there is a contrivance (not shown in the drawing) which arrests the movement of the rack, and so keeps the electrodes stationary. Before the apparatus is set to work, the proper distance for the charcoal-points is adjusted by means of the counterpoise O, which screws backwards or forwards on the short arm of the lever K, and thus regulates the movement of the rod M, N. If the light should go out, and the circuit be broken, the rod N immediately falls, pulling down with it the long end of the lever K. This presses upon one arm of the paul and gives motion to the wheel H, whereby the rack is elevated and the charcoal-points again brought into contact.

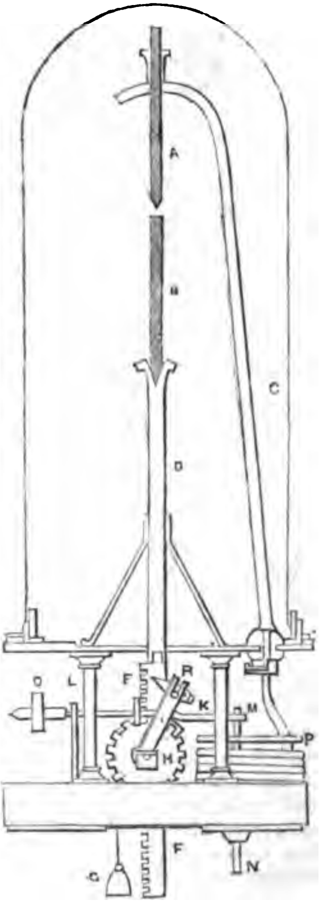

Fig. 59.

M. Lemolt's apparatus for adjusting the charcoal electrodes is somewhat different from the last. In the first place, the electrodes are not cylindrical, but are in the form of circular discs, *a*, *b*, Fig. 60; and they revolve freely on two arms, which move separately on one common axis *c*. This axis also carries a pinion, the square cogs of which are in communication below with the driving-wheel *d*, and above with another pinion *f*, the inner cogs of which are in gear with a large wheel *g*. Over the drum of the pinion at *c*, there passes two endless pulleys, which give motion to the charcoal discs *a*, *b*. In order that the discs may be at a proper distance for the production of a good light, there are two adjusting stops *h* *h*, fixed to the arms on which the discs rotate. These stops are brought into close contact with two cams, which are situated in the periphery of the wheel *g*; and as this wheel rotates, the charcoal discs are brought closer and closer together, so as to compensate for the wear of the electrodes. There is a spiral spring at *i* to keep the arms and their stops tight against the cams. The apparatus is thus set in motion—the terminal wires of the battery are brought into connection with the charcoal discs by means of the conductors *k*, *l*. The driving wheel *d* is then set in motion by clock-work within the case of the instrument, and its motion is communicated to the other wheels and also to the charcoal discs. The discs are then brought together so as to complete the circuit, and the stops are adjusted in the cams, so as to produce the necessary arc of flame. By the revolution of the discs, new surfaces are constantly presented to each other, and the old or worn edges are cleaned down by the sides of the stirrups in which they revolve.

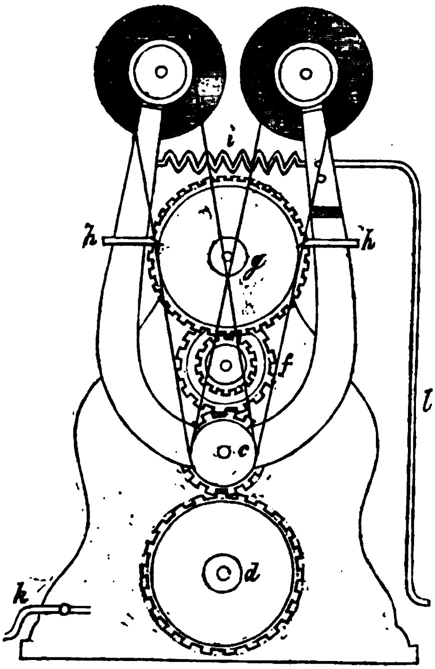

Fig. 60.

In Mr. Pearce's arrangement, there is a prismatic or cylindrical bar-electrode in contact with one, two, or three of a discoid form. These are moved by clock-work; and it is so managed, that while the first advances or rises through its sheath, the others revolve at a proper distance from it, and the edges are kept clean by means of iridium cutters. The charcoal bar is also held by the iridium conductors, which grasp it close to the ignited point. The advantage of this mode of mounting the electrodes is, that if from any cause, such as unequal waste of carbon, or irregularity of surface, the light should be extinguished at one point, the others remain burning, until by the further revolution of the disc, or the advance of the bar, the electrodes are again brought into contact, and the light restored. Besides which, in presenting two or three centres of light, so merged as to appear as one in a reflector, there is greater brilliancy and greater steadiness of flame.

Another apparatus has been patented by Mr. Pearce, which does away with the necessity of clock-work altogether. It consists of two bar-electrodes, which are approximated by means of springs or weights and pulleys; and the necessary distance is preserved by the intervention of slips of non-conducting charcoal. He has also contrived a plan for relighting the electrodes in case the arc of flame is blown out. This he effects by aid of a wedge-shaped piece of charcoal, which falls down between the electrodes directly the light is extinguished, and thus re-establishes the contact. The charcoal is fixed at one end of a lever, and to the other end there is a soft iron armature: this is placed opposite to a soft iron magnet, enclosed in a coil which carries the current. While the electricity is passing, the electro-magnet draws the armature to it, and so keeps the wedge-shaped piece away from the electrodes; but directly contact is broken, the armature retires, and the wedge-shaped piece falls down between the poles and re-establishes the arc.

Mr. Staite has patented a plan for obtaining a constant and uniform light by the ignition of a loop of platinum or iridium wire, enclosed in a glass globe from which the air has been exhausted. But there is no novelty whatever in this contrivance; and, consequently, it is undeserving of further notice.

Some little attention is necessary to the quality of the electrodes in order to get the best effect. *Common charcoal* is unsuited for the purpose, because of its being in most cases a non-conductor of electricity; the *charcoal of porous wood* is also objectionable, from the circumstance of its burning away very rapidly: therefore it is that electricians make choice of the densest varieties of carbon. One of these is the *charcoal from boxwood*, which is obtained by cutting the wood into pieces of nearly the required form, then putting into a crucible, filling up with fine sand, so as to secure the exclusion of atmospheric air, and exposing for two or three hours to a bright red or white heat. The crucible is to be well covered and allowed to cool before the charcoal is taken out.

Hard coke has been employed with considerable advantage by many persons. The objection to it is that it frequently scintillates, from the large quantity of iron which is contained in it. This difficulty may be overcome by powdering the coke, then stirring it about with a magnet so as to attract the iron, or else digesting it in nitro-muriatic acid and washing very well before drying. The powdered coke is then to be moistened with a little syrup or coal-tar, and rammed into a cylindrical mould: the bar which is thus made must be ignited in a crucible covered with sand, in the same way as that already described for the preparation of boxwood charcoal. These cylinders will be found exceedingly hard, and they give a light which is superior in whiteness and intensity to that from any other kind of charcoal. If the electrodes are soaked in a strong solution of common salt, and then dried, they give a still more brilliant effect; and by using a salt of copper, chloride of strontium, &c., we obtain green, red, and other coloured flames.

Again, it has been noticed that the intensity of the light is increased by removing the atmospheric air from the vessel containing the electrodes, and effecting contact in a rarefied atmosphere, or in a vacuum. The *effects* which are produced in this manner are very remarkable; for the purity and intensity of the light are greater than those from any other source. In the first place we find that it simulates the light of the sun, in the circumstance of its affording a means of distinguishing the most delicate tints of colour: blues, yellows, and whites, which are not to be seen in a pure state by ordinary artificial light, are recognizable by this mode of illumination as if they were seen by day. Again, when the light is decomposed by a prism, we obtain a spectrum which is similar to that afforded by the rays of the sun.

The intensity of the light has been variously estimated. That which was exhibited by Mr. Staite on the 30th of May, 1849, from the summit of one of the towers of the Hungerford Suspension Bridge, was said by him to be equal to 750 wax candles. Professor Grove, in experimenting with a battery of thirty cells, the platinum being four inches by two, obtained a light which equalled that of 1444 wax candles; and Dr. Letheby states, that in some experiments which were made by Mr. Hearder of

Plymouth, in the month of April, 1849, with a Maynooth battery of eighty cells, each four inches square, arranged in two sets of forty each, the light, when concentrated by a parabolic mirror, and sent over the country for a space of 5490 yards, gave a light equal to that of a candle at thirty feet distance; so that the intensity of the focussed light was equal to that of 301,401 candles. It is probable that Mr. Grove's estimate is nearest to the truth, as great pains were taken in his investigations to arrive at correct results.

It is very natural that a light of so great brilliancy should command a large share of public attention, and should likewise be made the subject of frequent experiment. Hence it is that Mr. Staite and others have often exhibited it in London and elsewhere. When it was shown from the top of the Hungerford Suspension Bridge, the light was sufficiently intense to illuminate the water-frontage of Somerset House; and when it was cast to the opposite side of the river, it lighted up all the buildings on the Surrey shore. Exhibitions of it have also been made at the Hanover Square Rooms, from the top of the Duke of York's Column, and from the portico of the National Gallery; but the most marvellous illustration of its power was afforded by Mr. Hearder of Plymouth, who placed the light at the top of the Devonport Column, and first experimented with it at Trematon Castle, which is distant about 18,266 feet; and then at Bovisand, which is 16,470 feet from the column. At the former place the light was sufficiently strong to mark the time on the seconds-hand of a small watch, and the walks of the castle were distinctly visible at a distance of half a mile; besides which, the ivy-leaves over the gateway of the building were plainly seen when the observer was sixty feet away from them. Its intensity, says Mr. Tucker, who reported upon it, was magnificently brilliant. At Bovisand the light was sufficiently strong to cast a shadow of objects on a yellow wall, and it was thought to be about equal in intensity to that of the full moon when at its meridian in a calm clear night. At that distance, without the reflector, it looked like the planet Venus when seen through a telescope.

The following are the accounts given of these effects as seen at Bovisand and Trematon by Messrs. Walker and Tucker, the two gentlemen who were deputed by Mr. Hearder to make the necessary observations. The accounts are extracted from the *Plymouth Herald* for April 21st and May 5th, 1849. Mr. Walker writes thus:—

"With regard to our observations at Bovisand. About half-past eight o'clock we saw flashes and glimmerings of a bluish light from the column at Devonport, which, to all but myself, were unsatisfactory. The people thought that something had gone wrong. The light was then, in all probability, on the Trematon side of the column, the column being directly between us and the light itself. After waiting for some time, we finally saw the electric-light outshining all the other visible lights, and we sent up a rocket or two to indicate our satisfaction. Our personal shadows were projected upon a boat-house door (painted yellow and itself illuminated) by the electric-light, and pronounced equal to that of the full moon when on the meridian in a calm clear night.

"A candle (six to a pound) projected a similar shadow upon the same door, illuminated in the same way, at a distance of 30 feet from the person whose shadow was thrown upon the door. That is to say, the shadow projected by the electric-light at a distance of 5,490 yards, was just equal to the shadow projected by a single candle at a distance of 10 yards. Consequently, their illuminating powers were as 10 (squared) : 5490 (squared), or as 1 : 301,401. This comparison is rather a 'stunning' one! I am of opinion that the electric-light possesses a space-penetrating power infinitely superior to any light we can obtain by combustion, since it is free from all carbonaceous or solid particles!

The Breakwater light may probably be equal to 24 Argand lamps, each equal to half a dozen candles; yet *this* light projected a shadow *only* slightly visible at a distance of 500 yards, while the electric-light projected shadows, at lucid intervals, strong enough for children to make *rabbits* with their fingers upon a wall more than 500 yards distant from the light itself; that is to say, ten times farther than from a lighthouse that could only throw a shadow 'faintly visible.' The electric-light, as seen in the open air, may be compared (as far as colour is concerned) to that of the planet Venus when seen through a telescope, or to the light of a glow-worm, or to those brilliant flashes of light we sometimes see within the Tropics from the waves when surcharged with phosphorescent matter."

And Mr. Tucker's account is as follows:—"Sir,—A variety of occupations have prevented my sooner informing you of the effect produced here by the electric-light, on the evening of the 12th inst. You are aware that this castle is 18,266 feet distant to the N.N.W. from the Column at Devonport. The reflector which you used was one from which the rays diverge. The evening was very favourable, but little breeze (E.N.E.) was stirring, yet sufficient to blow off the smoke from the town. The atmosphere was so clear that the Devonport lamps were very distinctly visible, and the stars which appeared shone very brightly; but they were few, and the moon had not yet arisen. The instant the light shone, the lamps of Devonport were all-but totally eclipsed; as it fell upon a sail spread over the walls of the keep, we immediately perceived that a shadow was cast by the fingers of a hand upon the sail, by a twig of ivy, and by the stem of an ivy-leaf. We could clearly see what o'clock it was by our watches. I ascertained the light to be polarized, and the whole effect was very striking, for the light upon the column was exquisitely beautiful—its brightness was magnificently brilliant. The interposition of the red shade then informed us that the light would be changed. When that change, whatever it were, was made, the light sensibly increased; we then could see the time by the seconds-hand of a small watch; the usual hand-writing was read; and the ivy-leaves on the gateway tower were seen at the distance of 90 feet. Persons more than half a mile behind the keep could plainly see the walks around it; and we all were very much pleased by the striking effect produced by your turning the reflector upwards towards the clouds, which we clearly saw, the light then having the appearance of the tail of a huge comet, the reflector being the nucleus. I think I may state that the breadth of the intensity of the light was at least three-quarters of a mile; and I believe that persons standing on the Brick-field (close to Devonport) saw the light reflected to them from a looking-glass which was suspended from the keep."

If the electric-light is exhibited in a room where there are gas or other lights, the intensity of the former is so great that it actually produces shadows of the flames of the others. At the Polytechnic Institution the electric-light is used for the purpose of illustrating the optical effects of refraction and reflection in a stream of water—as seen in Duboscque's fountain; and at the Panopticon, the spray from the large *jet d'eau* is illuminated by several electric-lights that were placed at the very top of the dome. The chromatic effects are produced by means of coloured glass, which is rapidly shifted before the light.

As to the economy of the light, little can be said. Professor Grove stated, that in his experiments with the battery which gave the light of 1444 wax candles, the cost was at the rate of about 3*s.* or 3*s.* 6*d.* per hour; and Mr. Ward, who has devoted attention to this part of the subject, states that to obtain a given light with 100 pairs of Smee, 55 of Daniell, or 34 of Grove, each cell consuming 60 grains of zinc per hour, the cost would be about 6*d.*, 7½*d.*, or 8*d.* per hour respectively. But we apprehend that this does not include the original cost of the battery, or the charge for attendance. At the Royal Opera House, where the light was exhibited for several nights in a new ballet, it cost the manager £2 per night, although the exhibition was not of long duration, and was under the superintendence of Mr. Staite himself. In this case a Maynooth battery of seventy-five cells was employed.

This clearly indicates that the light can never be economically employed as an ordinary illuminating agent: indeed, it is manifest that as the source of power is really the same as that of other artificial lights,—namely, the oxydation of a combustible body,—it resolves itself into this, whether it is cheaper to burn gas, oil, or tallow, by means of atmospheric oxygen, or to consume zinc by the aid of water and very expensive acids. Of course some allowance must be made for the value of the products in the latter case; but then, as a set-off to this, we have to consider the expense of constructing the batteries, and of attending to them. It will, however, be freely admitted that, although it is not an economical light for ordinary purposes, it may be advantageously employed whenever a vast amount of illuminating power is required, and there are facilities for charging the batteries. It might be employed, for example, in light-houses, perhaps also in mines, in theatres, and for public exhibitions of various kinds. It has been stated that the electric-light has been used to illuminate the works of the Napoleon Docks in Paris, where the men are employed night and day in their work. The light has been employed there for four months at a cost of thirty-six francs per night: and as it served for the use of 800 men, the cost was exactly four and a half centimes, or less than a half-penny, per man. This does not look like a very expensive mode of illumination; and it is very probable that it may be resorted to in such cases as this with considerable advantage. Again, it is not altogether impracticable to have an electric-light in some convenient part of a mine, and, by the aid of reflectors, to throw the light along the different galleries and into the workings. By this means all danger from explosion in those localities where the fire-damp abounds would be completely obviated.

The Steel Mill of the Miner is the last form of apparatus for the production of artificial light to which we shall allude. Before the introduction of the Davy-lamp into the coal-mines of this country, a rude instrument was employed by the miner for the generation of light in those localities where the fire-damp rendered the atmosphere unusually dangerous. It consisted of a small steel wheel, which was made to revolve very fast by means of a small pinion that was turned by hand; and while the wheel was revolving, a piece of flint was held against it, so as to emit a brilliant shower of sparks. These gave out sufficient light for the miner to work by. It was thought that the heat from this apparatus was less dangerous than that from a candle, but Dr. Pereira succeeded in firing explosive gas with it, and thus demonstrated to the Parliamentary Committee that it was just as dangerous in a mine as a candle. At the present time the instrument is quite out of use.

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